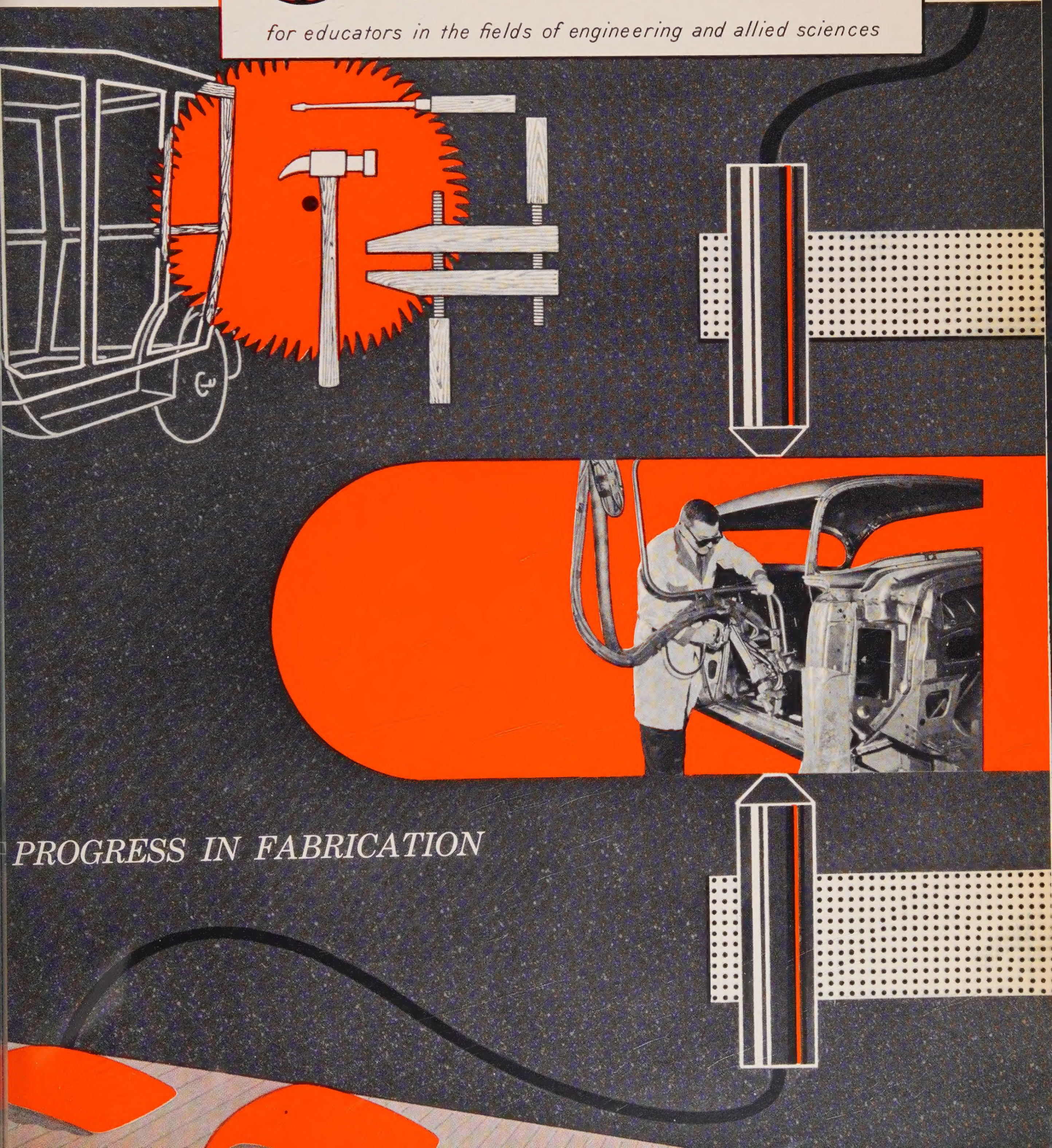
GENERAL MOTORS
ENGINEERING JOURNAL
Volume 3 July-August-September 1956 Number 4
for educators in the fields of engineering and allied sciences



Some Thoughts on Perceptiveness

Engineering is often referred to as an exact science, but experience indicates that in many instances it is not. In essence, engineering consists of applying the fundamentals of such pure sciences as physics and chemistry toward the solution of a problem with the aid of the exact tool of mathematics. Yet there is much more to practicing engineering than merely the mechanical application of scientific fundamentals; there is a certain degree of art, or craft, involved. If there were not, no premium would exist on the valuable commodity called experience, for in the final analysis experience is simply the development of skill, or art, in the practice of a particular profession or trade. There is no doubt that the seasoned engineer can produce more masterful results than the novice graduate, yet both have essentially the same training in the basic sciences.

Possibly the quality that I am thinking about here can be expressed most aptly by the word "perceptiveness." Experience is a prerequisite for it, creativeness and imagination help to develop it, and intuitiveness aids in knowing when and how to apply it. Perceptiveness is that intangible quality of the seasoned engineer which is difficult to evaluate in words but which is readily discernible in his work. There is no doubt that perceptiveness and other similar attributes—imagination, creativeness, and intuitiveness—are all closely interrelated, for the individual who displays any one of these traits to a strong degree usually is quite well endowed with the others.

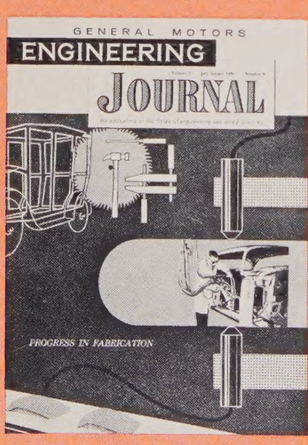
The degree to which a particular piece of engineering work can be termed masterful depends largely upon the amount of perceptiveness that went into the effort. In this connection, it was through perceptiveness that engineers in General Motors transmission development group recognized the need for a satisfactory automatic drive for heavy-duty trucks and conceived and developed the idea of using differentially driven automatic transmissions in parallel. The Twin Hydra-Matic truck transmission, as it is known, consists of 2 standard Hydra-Matic transmissions driven through a fluid coupling and differential which guarantee equal input torque to each transmission. The output of each transmission is so geared to the final drive shaft that one transmission runs 25 per cent faster than the other. This causes each of the 2 transmissions to shi[ft] at points midway between those of th[e] other, providing a 7-speed drive wi[th] small steps between ratio change from standard 4-speed transmissions.

The importance of perceptiveness i[n] this example is that its application n[ot] only satisfied the automatic transmissio[n] requirements of heavy load-carryin[g] highway trucks, but eliminated an exten[-]sive developmental program and cost[ly] tooling program inherent in any ne[w] design.

Perceptiveness is a characteristic whic[h] is not innate or inborn; rather it is [a] quality which every engineer can devel[op] in himself if he has a sincere desire to do s[o].

Perhaps, then, engineering is not tru[ly] an exact science. There is some art, [or] craft, required in its practice. The suc[-]cessful engineer is one who has develope[d] in himself the quality of perceptiveness.

Charles A. Chayne,
Vice President in Charge
of Engineering Staff



THE COVER

Through the years increased complexity in automotive body contours has required body engineers to constantly introduce new methods of body fabrication which not only improve quality, lower cost, and increase production but also assure rigid dimensional control of all body openings for doors, windshields, and other items. This issue's cover design by artist John B. Tabb symbolizes progress in automobile body fabrication. The early automobile body's wooden frame structure, which was fabricated by carriage makers who used simple hand tools, has been replaced by an all-welded steel body structure. The manufacture of today's automobile body is symbolized by the welding electrodes and the illustration of a typical welding operation. In a like manner, the many hand operations used to form body panels of early-day automobiles have been replaced by giant presses which stamp entire roof panels and other body sections having complex curved surfaces.

CONTENTS

GM LABORATORIES AT WORK

TECHNICAL COMMENTARIES

ENGINEERING NEWS

OTHER FEATURES

GENERAL MOTORS ENGINEERING JOURNAL

Vol. 3 July-August-September 1956 No. 4

Published with the help of General Motors engineers everywhere

The GENERAL MOTORS ENGINEERING JOURNAL is published quarterly by the Educational Relations Section of the Public Relations Staff, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

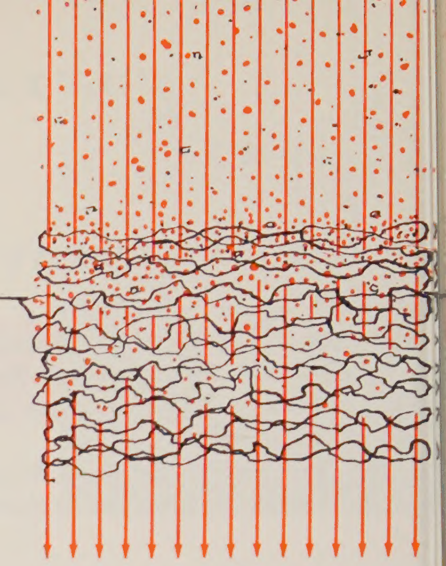
JOHN BRYANT, Editor
RAYMOND O. DARLING, Associate Editor
THOMAS F. MACAN, Assistant Editor

ERNEST W. SCANES, Art Director
JOHN B. TABB, Asst. Art Director

D. O. BRYSON, Production Manager

Address: EDUCATIONAL RELATIONS SECTION, Public Relations Staff, GM Technical Center, P.O. Box 177, North End Station, Detroit 2, Michigan.

New Test Facility Provides High-Capacity Air Flow for Automotive Air Cleaner Development



At AC Spark Plug Division efficiency and restriction tests are performed on automotive air cleaners under controlled laboratory conditions. Through the years it has become necessary to modify the air cleaner testing facility from time to time to meet an ever increasing air cleaner air-flow demand resulting from the steady rise in power output of carbureted internal combustion engines. In late 1954, when modification again became necessary, AC Spark Plug engineers decided to completely redesign the testing facility to provide for both present and future air-flow requirements. As a result, an air-flow test facility was recently installed which is capable of providing up to 4,000 cu ft of air per minute. By comparison, one of the early models used by AC required only 300 cfm. In addition to providing sufficient air-flow capacity for present and future requirements, the facility also includes fully automatic control features to vary the air flow through a prescribed cycle which represents the varying air-flow demand of an engine during actual operation.

AIR cleaners are installed at the carburetor air intake of internal combustion engines to prevent the entry of abrasive dust particles into the engine. Such particles, if allowed to enter, would cause excessive wear of engine parts, particularly the top piston ring and cylinder wall. The principal types of air cleaners used today for carbureted internal combustion engines are the *oil-wetted* and *oil-bath* types.

In the oil-wetted type of air cleaner, also known as the surface-adhesion type, air to be cleaned is passed through an oil-soaked filter medium which retains all dust particles impinging upon its surface. The filter medium, formed of either metallic wire, ribbons, animal hair, or vegetable fibers, is designed to provide the maximum number of "targets" for dust particles to strike without unduly impeding air flow through the medium.

As may be expected, the ability of an oil-wetted type air cleaner to collect dust particles decreases as the oil on the filter medium becomes soaked-up by the particles already collected. This decline in dust collecting ability is accompanied by a slight rise in impedance to air flow due to the corresponding decrease in the air passage area. The filter medium then must be removed and thoroughly cleaned and re-oiled. When it is expected that an engine will be operated under conditions where dust concentrations will be sufficiently high to necessitate frequent cleaning and re-oiling of an oil-wetted type air cleaner, the oil-bath type air cleaner is usually specified.

The oil-bath type air cleaner combines the surface-adhesion filter medium with an oil reservoir. Air to be cleaned is first directed upon the surface of the oil reservoir where it loses a major portion of its dust load. Fresh oil from the reservoir is carried into the filter material by the action of the air flowing through the air cleaner. This serves to keep the filter medium constantly washed clean and re-oiled.

If the velocity of air passing through the filter element of an oil-bath type air cleaner is great enough, the oil in the filter element will be carried through the element and into the carburetor. This reduces the amount of oil available for further cleaning. Also, the oil entering the carburetor contains dust particles which will cause wear of engine parts. To prevent this occurrence, the oil-bath cleaner must be designed so that its *pullover capacity*, or that rate of air flow at which the oil will be pulled or drawn through the filter element, is higher than the maximum rate at which air will be drawn through the cleaner by the specific engine on which it is used.

Air Cleaner Efficiency and Restriction

The engineer concerned with engine performance must be supplied with data on the efficiency of an air cleaner, its removal of dust from the incoming air stream, and also information regarding its restriction, or pressure drop, and the rate that this restriction increases as dust particles are collected. The restriction or pressure drop through an air cleaner is determined by measuring the difference between the static pressure (in. of water) at the cleaner's inlet and outlet at the maximum air-intake demand (cu ft per min) of the engine.

The restriction and rate of restriction increase of an air cleaner affect the engine's power output and, in the case of carbureted engines, may affect fuel economy by limiting the amount of air that will enter the cylinder. An air cleaner, for example, which has a restriction of 1 in. of water higher than another may cause a reduction in power output as much as 1 hp or 2 hp. If the restriction increases as dust is collected, not only will the power output be reduced but the fuel consumption may be increased since a lowered air pressure in the carburetor resulting from a restricted air cleaner may cause it to produce a rich air-fuel mixture. In a passenger car engine there may be a loss of 1 mile per gallon for each 1 in. of water increase in air cleaner restriction.

Efficiency and restriction characteristics of air cleaners must be determined in the laboratory to forecast their effect on the wear and performance of the engines on which they will be used. Air cleaner efficiency determinations are usually performed at maximum engine air-intake demand and at 1 or more fractions of maximum representing part-throttle operation. In some cases, as when specifications outlined by the Society of Automotive Engineers Tractor Code or the U.S. Army Ordnance are followed,

By LUCIAN B. SMITH*
and WESLEY W. McMULLEN
AC Spark Plug Division

Testing and developmental facilities must advance along with the engine itself

efficiency determinations are made with the air-flow rate varied through a prescribed cycle intended to represent the varying air demand of the engine in actual vehicle operation.

To obtain accurate efficiency and restriction test data for air cleaners, suitable laboratory equipment is necessary to produce and control the required flow of air. Means also must be provided for measuring the air flow, measuring restriction, feeding dust to the air cleaner, and for collecting and measuring the dust which passes through the cleaner.

Early AC Air Cleaner Developmental Testing Equipment

The automobile engine air cleaners first produced by AC Spark Plug Division were about the size of a 1-quart can. Maximum automobile engine size at that time was about 84 hp and required a maximum air flow through the carburetor of approximately 160 cfm. At present, passenger car engines are rated as high as 300 hp and require an air flow through both the carburetor and air cleaner of approximately 420 cfm. Military and commercial vehicles also have increased in size and power so that air cleaners are now being developed with capacities as high as 2,000 cfm.

Paralleling the ever increasing size of engines and air cleaners has been the development of equipment used by AC Spark Plug's Automotive Test Laboratory to measure the efficiency and restriction of a great variety of air cleaners.

The first air-flow test equipment used by AC Spark Plug in 1925 was comprised of a 300-cfm motor-driven blower, hand-operated air-flow control valves, and a vertical orifice tank containing removable orifices and a mercury seal. A 500-cfm motor-driven blower was installed a few years later in conjunction with a horizontal orifice tank which contained several round-edge orifices of various diameters (Fig. 1). The orifices were built into an orifice plate in such a manner that the proper orifice size could be utilized by plugging those orifices not wanted and leaving the desired orifice or orifices open.

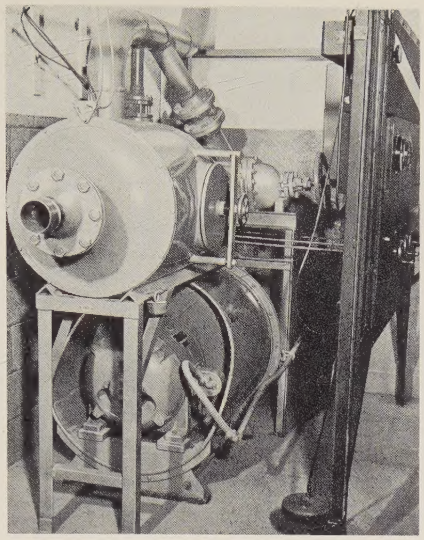


Fig. 1—The first major modification made in AC Spark Plug's air cleaner testing facility consisted of increasing the air blower capacity from 300 cfm to 500 cfm and changing from a vertical to a horizontal orifice tank. The tank was positioned on a stand above the blower, which was driven by a 25-hp motor. The test facility's control panel is shown at the right in the picture.

By 1941 the size of air cleaners had increased to such an extent that it became necessary to install a 1,000-cfm air blower, larger diameter orifice tank, and auxiliary equipment (Fig. 2). It was thought that equipment of this capacity would be sufficient to meet requirements indefinitely. In 1954, however, it was realized that air cleaners in the 2,000-cfm class were in the not too-far-distant future, and a decision was made to design and build air cleaner testing equipment of higher capacity.

The need was realized for increasing the capacity of testing equipment to approximately 4,000 cfm. It also was decided to design the equipment to include fully automatic control for varying capacity air-flow test programs, automatic recording of test data, and fast-acting and positive air-flow regulators—in general, an overall compact system which would provide maximum convenience for a single operator. AC test engineers drew up the basic design specifications for the air-flow test stand and then turned the project over to the Process Development Section, an activity of the General Motors Manufacturing Staff, to be completely detailed and constructed.

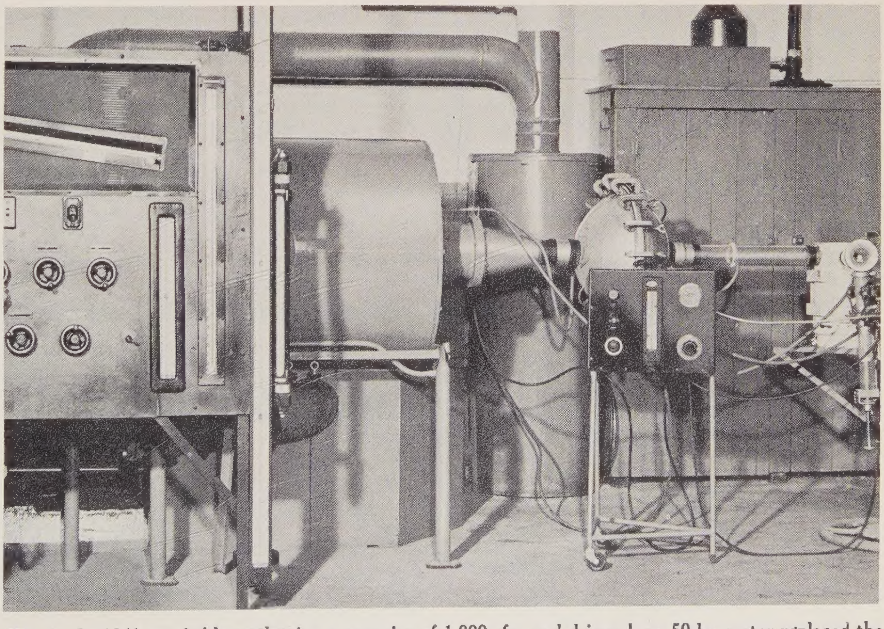


Fig. 2—In 1941 an air blower having a capacity of 1,000 cfm and driven by a 50-hp motor replaced the previously used 500-cfm capacity air blower. A larger diameter horizontal orifice tank, part of which is visible behind the control panel, also was installed. Shown connected to the outlet of the orifice is the absolute filter and dust-feed control equipment. At the extreme right is the dust feeder and air cleaner.

*For Mr. Smith's biography and photograph, please see p. 55 of the January-February 1956 issue of the General Motors Engineering Journal. This is the second paper contributed by Mr. Smith, chief test engineer in the Automotive Test Laboratory, AC Spark Plug Division.

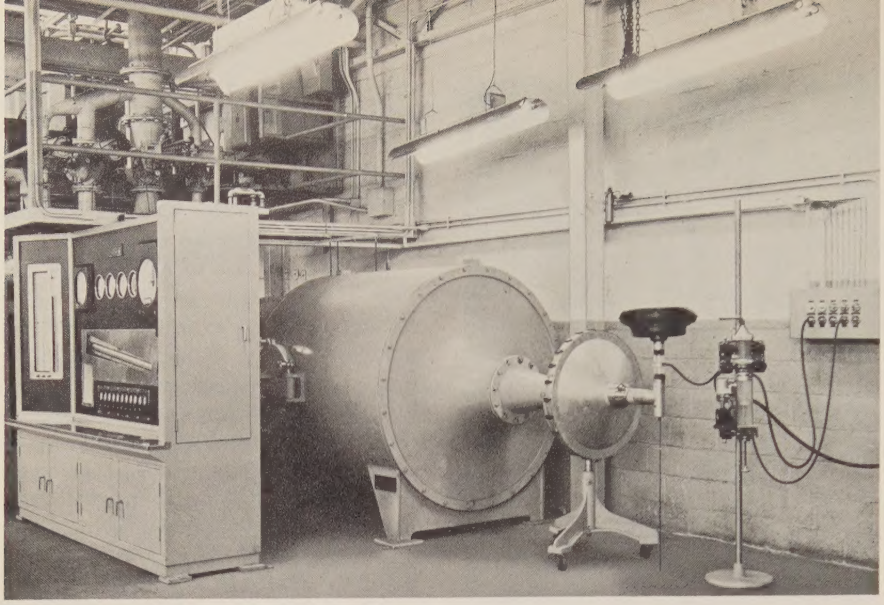


Fig. 3—The newly installed automotive air cleaner air-flow test stand provides air flows up to 4,000 cfm. Shown at the left is the control console. Immediately behind the console is the 6-ft diameter orifice tank. Connected to the outlet of the tank is the 30-in. diameter absolute filter and, in turn, the air cleaner under test. The dust-feeder mechanism and manometer-connection terminal box are mounted on the wall at the extreme right. Located on a balcony above the control console and orifice tank is the "valve tree" which contains the 5 air-flow control valves. For the sake of clarity, connecting tubing between the air cleaner and dust-feeder mechanism has been omitted.

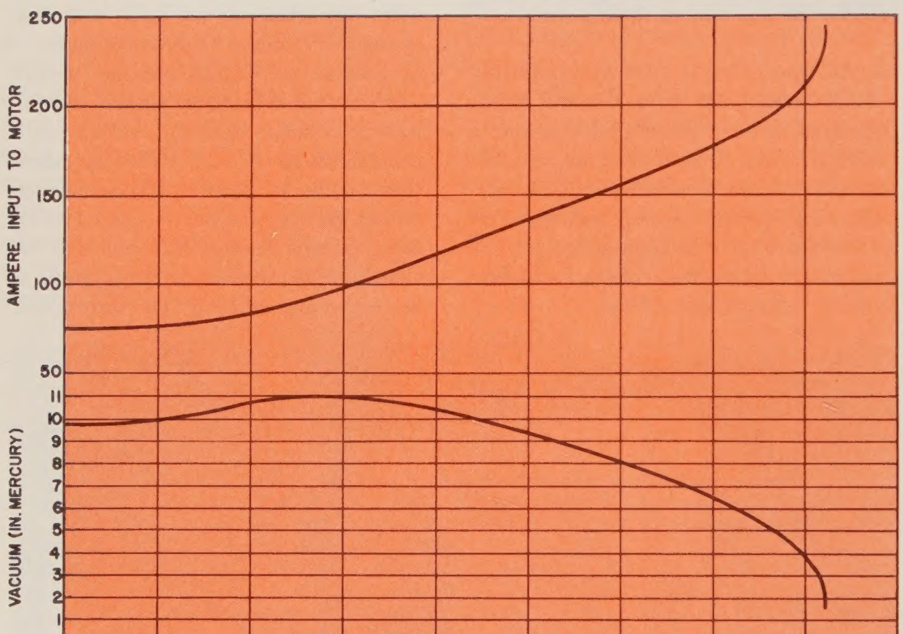


Fig. 4—The use of a 200-hp motor extends the operating range of the blower to 4,000 cfm. The blower used is rated at 2,325 cfm at 10-in. Hg. The performance characteristics shown were run at an inlet air temperature of 70° F and a barometer reading of 29.92-in. Hg absolute.

An overall view of the AC Spark Plug Automotive Test Laboratory's recently installed 4,000-cfm air-flow test stand shows its principal components: air cleaner in test position, means for feeding dust, orifice tank, control console, and air-flow valves (Fig. 3).

Air-Flow Test Stand Equipment

Air flow for test purposes is supplied by a blower driven by a 200-hp motor. The blower pulls air through a tank containing 9 orifices of appropriate diameter mounted in an orifice plate. The 9 orifices enable the air flow to be measured over the entire range of the test system at a differential pressure across the orifice plate of from zero to 6 in. of water. Air flow, measured in cfm, is read directly from calibrated scales mounted on a 6-in. inclined manometer. This manometer is connected across the orifice plate and is centrally located on a control console.

Air flow is regulated by 4 control valves which are connected in parallel and this overall valving combination is connected in series with one 12-in. diameter control valve. These valves, connected between the blower and the orifice tank, give full coverage of the system's capacity in smooth increments and vernier variations. The control valves are operated by fast-acting pneumatic actuators which, in turn, are controlled either manually or automatically at the control console as test conditions may dictate. The series system of air-flow control valving offers economy in that the blower is not required to operate at full load to achieve partially rated air flow.

Motor and Blower

The test system is powered by a 200-hp, 3,500-rpm, 440-v, 3-phase, delta-connected, totally enclosed a-c motor which drives a blower rated at 2,325 cfm at 10-in. Hg. The use of the 200-hp motor extends the operating range of the test system to 4,000 cfm (Fig. 4). The motor and blower are mounted on the roof of the Automotive Test Laboratory to conserve space and eliminate noise inside the Laboratory.

Orifice Tank

The orifice tank is approximately 6 ft in diameter and 10 ft in length (Fig. 5). Contained in the tank's orifice plate are 9 orifices, built to standards developed by GM's Research Staff, having diameters of ⅞ in., 1⅛ in., 2 in., 2¾ in., and 3⅝ in., and 3 orifices of 5 in. diameter (Fig. 6 left). The orifices are arranged in the orifice plate so that each is located 2 diameters or more distant from any adjacent orifice (Fig. 6 right). This arrangement permits parallel operation when necessary with minimum interference between the air streams.

Air-Flow Control Valves

The 4 air-flow control valves, connected in parallel between the turbine's intake and the orifice tank, have diameters of 2 in., 3½ in., 5 in., and 8 in. (Fig. 7). The 4 valves, in turn, are connected in series with the 12-in. diameter valve directly connected to the turbine

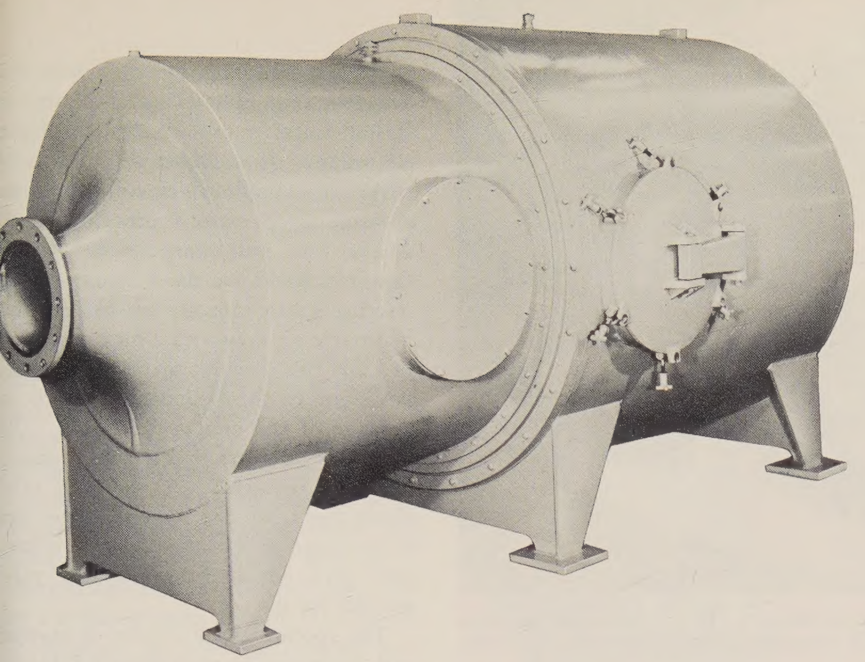


Fig. 5—The orifice tank used in conjunction with the air-flow test stand is 6 ft in diameter and 10 ft long. Located at approximately the center of the tank is an orifice plate containing 9 calibrated orifices of various diameters. Air flow through the tank is from right to left.

intake. The 12-in. valve is used primarily as a surge limiter during manual operation of the test system and as a flow limiter during automatic operation. By using the 12-in. valve as a flow limiter during automatic operation, it is possible to utilize the full range of one of the 4 smaller diameter valves to vary the flow rate, thereby achieving a more exact air-flow demand program. The 5 valves are operated by pneumatic cylinders which receive control pressure from the control console.

Control Console

The control console is a completely integrated system of controls and recording and integrating devices which provide the operator with a means for fast and efficient control of the system, in addition to providing all pertinent data relative to

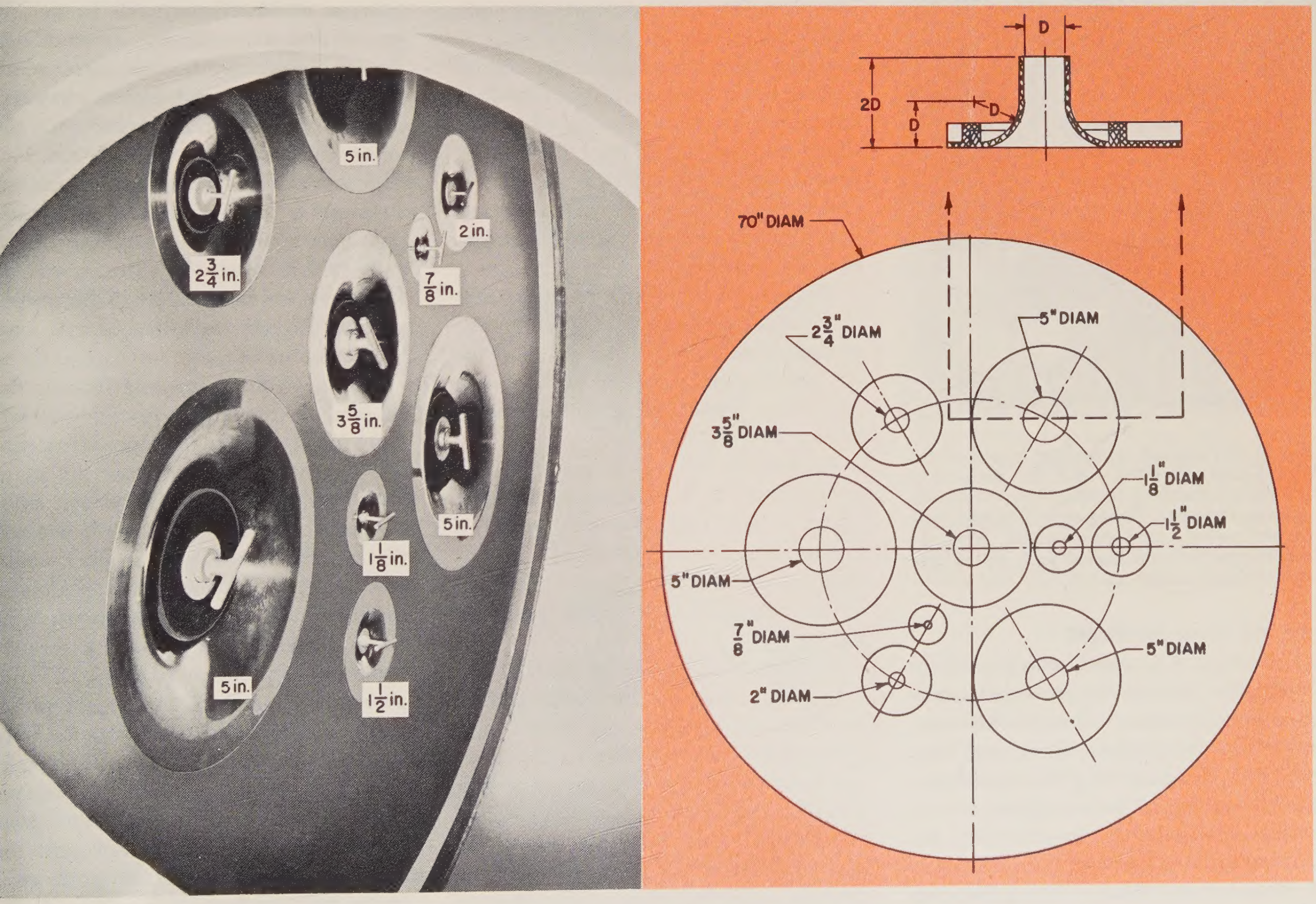


Fig. 6—(Left) The orifice plate contains 9 calibrated orifices of various diameters. Each orifice has an expanding plug. In operation, 1 or more of the orifices are unplugged to obtain the required air flow. (Right) Each orifice in the orifice plate is 2 diameters or more away from an adjacent orifice permitting parallel operation, when necessary, with minimum interference between the air streams.

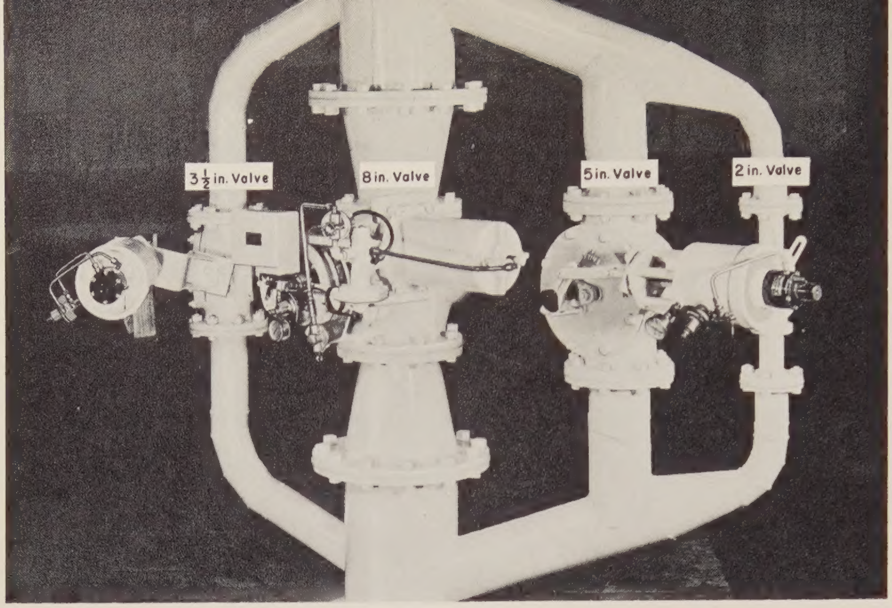


Fig. 7—Four air-flow control valves are connected in parallel between the blower's intake and the orifice tank in an arrangement called a "valve tree." The control valves are operated by fast-acting pneumatic actuators.

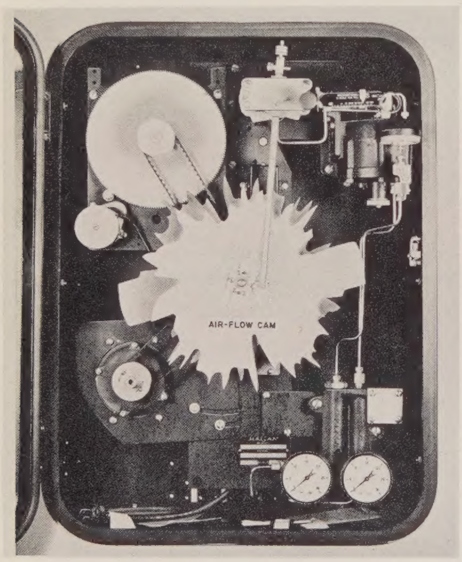


Fig. 8—The program transmitter housed in the control console is fitted with a cam designed to produce a 10-minute, varying air-flow cycle for dust-capacity tests. During each 10-minute cycle the cam makes 1 complete revolution. When the cam follower is at the highest point on the cam, air flow is at a maximum.

the test being conducted.

The control console houses a program transmitter which is a pneumatic-operated signal generating device. The transmitter has an irregularly shaped cam which is designed to give a predetermined varying air-flow program over a period of 10 minutes' duration (Fig. 8). During the 10-minute run the cam makes 1 complete revolution. The generating signal is sent from the program transmitter to a recorder-controller unit on the control console which indicates and records the demand signal. The signal is then fed to the flow-control valve operator-cylinders to obtain the air flow requested by the program transmitter. The recorder-controller unit also indicates and records air flow corrected to standard conditions. This is accomplished by automatically compensating for varying pressures at the orifice inlet which may be caused by a varying air pressure drop through the air cleaner under test (connected to the orifice tank inlet) and barometric pressure changes of the atmosphere.

The control console also houses a differential pressure-recorder which is connected across the inlet and outlet of the air cleaner under test to indicate and record the restriction of the cleaner to the air flow.

Located on the control console panel are a zero-in. to 30-in. water manometer, a zero-in. to 90-in. water manometer, a zero-in. to 30-in. mercury manometer, temperature indicator, barometer, and various control switches and indicator lights.

A separate section of the control console panel is used for dust-feeder control instrumentation. Flow raters and flow controls are used to indicate and control the quantity of air used to inject dust particles into the inlet air stream entering the cleaner. The dust feeder is capable of feeding 900 grams of dust at rates from zero grams per minute to 100 grams per minute. The rate of dust injection is controlled by adjusting the speed of a variable-speed motor which drives a plunger to feed a column of dust into the feeding chamber (Fig. 9). A vibrator agitates the dust chamber to prevent dust sticking to the walls of the chamber.

As an example of how the program transmitter operates, assume that an air cleaner has been connected to the air-flow test stand for the purpose of conducting a dust-capacity test to be run at a variable air flow with a maximum flow of 1,200 cfm. For this specific test a scale is selected on the inclinometer which has a range of 400 cfm to 1,325 cfm. This scale also indicates that a 5-in. diameter orifice is required. A reference table shows that 1,200 cfm is about 90 per cent of the range of the 3½-in. air-flow control valve, which makes this size valve suitable for the test.

The motor-driven blower is started and, by manually controlling the 3½-in. valve, the desired air flow of 1,200 cfm is established. Since it is desired that the automatic controls take over, the recorder-controller unit and program transmitter are switched on. As the cam follower of the transmitter's irregularly shaped cam moves up and down during the cam's rotation, the transmitter sends an air pressure signal to the recorder-controller. The controller "senses" the amount of air flowing through the 5-in. diameter orifice and, in turn, sends an air-pressure signal to the automatic positioner of the 3½-in. air-flow control valve which causes the valve to assume a position which will permit the proper air flow through the orifice as called for by the transmitter.

The question may arise as to why the recorder-controller is necessary—why is it not possible to send the air pressure signal from the program transmitter directly to the 3½-in. valve's automatic positioner mechanism? This is not possible because the transmitter sends a signal which would produce the correct air flow only under a certain condition of absolute pressure at the orifice inlet. The recorder-controller compensates for changes in the absolute pressure by means of an element which senses a change in conditions, namely restriction build-up in the air cleaner during dust feeding. The controller receives the signal from the transmitter which, in the foregoing example, calls for 1,200 cfm. As conditions change, the controller inserts a correction and sends the proper signal to the valve's automatic positioner mechanism thereby maintaining proper air flow.

During a dust-capacity test, dust is fed into the air cleaner until the restriction reaches 20 in. of water at maximum air flow on 2 successive test cycles. The amount of dust required to produce the 20 in. of water restriction is the criterion of dust capacity.

Absolute Filter

An absolute filter (Fig. 10) is used to collect any dust particles passing through an air cleaner under test. The filter is connected to the outlet of the air cleaner during efficiency tests. The filter housing is constructed of 2 halves each 30 in. in diameter with 6-in. diameter inlet and outlet tubes. Placed in the filter are 2 layers of canton flannel cloth which collect any dust passing through the cleaner. By weighing this filter cloth before and after each test and knowing the amount of dust injected into the air stream during the test, the efficiency of the air cleaner can be accurately determined.

Operation and Tests

On the new air-flow test stand, manual operation is used for the majority of tests. Suitable controls on the console are manually operated to set the position of the pneumatic air-flow control valves. When efficiency and restriction-increase tests are made under varying air flow conditions, however, automatic control is used. The program transmitter causes the air flow to follow a specified pattern in 10-minute cycles. These cycles are repeated until enough dust has been caught by the air cleaner to raise its restriction to a predetermined limit at which time the test is then terminated.

As an example of the sequence of events which take place during a test, assume that an efficiency test is to be conducted at 200 cfm on an oil-bath type air cleaner. Assume also that 101 grams of dust are to be fed to the air cleaner during a 30-minute period.

The oil reservoir of the cleaner is first filled with a recommended grade of oil. The cleaner is weighed, the weight recorded, and the cleaner is then connected to the air-flow test stand with the absolute filter between it and the stand.

A check is made to see that all air-flow control valves are set for manual control and are in the "off" position. The turbine motor is then started, and the 12-in. diameter throttling valve is slowly opened to about 15 per cent of full opening. The 2-in. diameter air-flow control valve is then slowly opened until air is flowing at 200 cfm through the air cleaner. The temperature and pressure existing in the plenum chamber at the entrance to the orifices is next checked. These readings are then inserted into the compensating device on the inclinometer in order to correct the air flow to standard conditions. (Air flows are expressed in GM Standard Air Conditions which are cfm-corrected to 29.704 in. Hg at 80° F.) If during a test there is a noticeable change in the pressure or temperature, the air flow must be readjusted by inserting the new values.

After the dust feeding has been completed, the air-flow test stand is shut down and the air cleaner removed and reweighed. If, for example, the air cleaner weighs 95 grams more than it did previous to the dust feeding, the indication is that the cleaner caught 95 grams out of the 101 grams it was fed and that some dust went through the cleaner and into the absolute filter. If the canton flannel cloth of the absolute filter gained 5 grams in weight, the oil-bath type cleaner caught 95 grams of dust and 5 grams went through it and into the absolute filter. This adds up to 100 grams. Originally, 101 grams of dust were placed in the dust feeder. This amounts to a difference of 1 gram which can be assumed to have clung to the dust feeder or fittings and did not actually get to the cleaner.

The efficiency E of the air cleaners expressed in per cent, is simply the ratio of the quantity of dust caught by the cleaner to the quantity of dust entering the cleaner or, in this example, $E = 95/95 + 5 = 95$ per cent.

The restriction build-up of the air cleaner due to the dust collected in the cleaner is checked and recorded by measuring the pressure drop (in. of water) across the cleaner at the specified air flow.

Summary

The flexible design of the new air cleaner air-flow test stand allows developmental tests to be performed efficiently and with maximum convenience. The automatic control features permit air cleaners to be tested under the varying air flows encountered during actual engine operation. The availability of air flows up to 4,000 cfm provides for present requirements and allows developmental work to be easily performed on air cleaner designs for engines of the future.

Fig. 9—The dust-feeder mechanism is capable of feeding 900 grams of dust at rates from zero grams to 100 grams per minute. A variable speed motor drives a plunger which feeds a column of dust to the air cleaner. The plunger is located inside a transparent dust cylinder shown to the right of the motor.

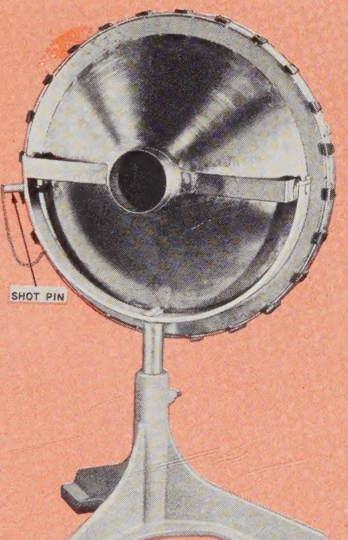


Fig. 10—The absolute filter is comprised of 2 30-in. diameter housings and 6-in. diameter inlet and outlet tubes. Placed in the filter are 2 layers of canton flannel cloth used to collect any dust which passes through the air cleaner during efficiency tests. The cloth is carefully dried and weighed before and after each test for the purpose of determining the amount of dust collected.

The Use and Properties of Non-Flammable Liquids in Manufacturing Processes

By DAVID MILNE*
General Motors
Manufacturing Staff

A liquid must have more than non-burning properties before it can be accepted

The general nature of liquids used by General Motors in the manufacture of its products was described in the paper "The Care and Handling of Liquids in Manufacturing Processes," which appeared in the March-April 1956 issue of the GENERAL MOTORS ENGINEERING JOURNAL. This paper outlined the difficulties and hazards involved when using flammable liquids in production and the factors to consider when substituting less flammable liquids for them. There is still another area to consider with regard to elimination of flammable liquids in production. This area deals with employing non-flammable liquids as substitutes for the flammable liquids usually used, for example as hydraulic fluids, coolants for various machine operations, metal cleaning solvents, and quenching oils. Substitution of a non-flammable liquid for a flammable one is no simple matter and requires careful consideration and extensive evaluation tests before the liquid substitute can be used. The characteristics and properties of a non-flammable liquid used as a substitute in a particular manufacturing operation must, in addition to providing safer working conditions, have no adverse effect upon the efficiency of the equipment or operation in which it is to be used.

LIQUIDS play a very important role in the performance of various manufacturing processes. For example, hydraulic fluids, coolants, metal cleaners, and rust preventives are but a few of the many applications found for liquids in manufacturing.

Unfortunately, the majority of liquids used in manufacturing are flammable and, as such, are an ever-present potential fire hazard. In view of this, a great deal of caution must be exercised to lessen the hazards involved when using flammable liquids.

Three methods are available to lessen the hazards involved: (a) use of a less flammable liquid, (b) substitution for the manufacturing process using a flammable liquid a process which will produce equal or better results without the use of flammable liquids, and (c) substitution of a non-flammable liquid for the flammable liquid. It is in this last method that recent noteworthy advances have been made and with which this discussion will be concerned. Eight general manufacturing process areas in which non-flammable liquid substitutes are employed by General Motors will be discussed as follows:

(a) Hydraulic fluids
(b) Machining operations
(c) Metal cleaning
(d) Sound deadeners
(e) Rustproofing
(f) Stretcher rolling
(g) Painting
(h) Quenching of heat treated metals.

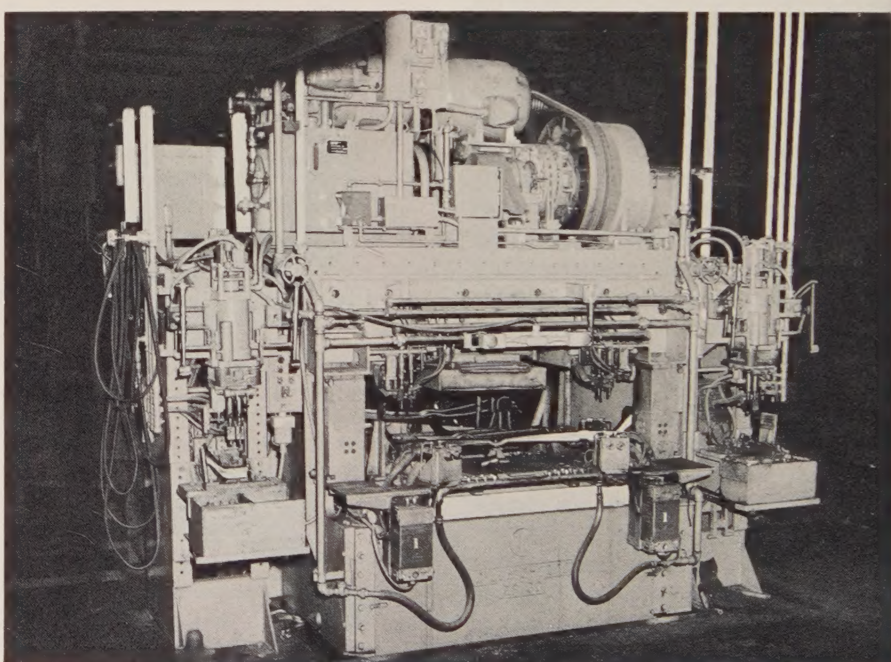


Fig. 1—This hydraulically operated press welder represents but one example of where a non-flammable liquid was successfully substituted for a flammable, petroleum-base hydraulic fluid. Many factors had to be considered, however, before a non-flammable liquid could be substituted. Typical of the properties required for the non-flammable liquid used were, in addition to its non-flammable characteristics, its toxicity, lubricating quality, viscosity, compressibility, specific gravity, stability, and foaming action. It was highly important that the substitute non-flammable liquid have essentially the same characteristics as the flammable hydraulic fluid it was to replace in order that satisfactory machine operation be maintained. The basic types of non-flammable liquids available as substitutes for hydraulic systems at present are oil-in-water emulsions, water-base solutions, and organic liquids, such as phosphate esters and chlorinated products.

Hydraulic Fluids

Hydraulic fluids are media for transmitting power needed for the performance of various machine operations in manufacturing processes. The usual hydraulic fluids are carefully selected and blended petroleum oils and, in use, are frequently subjected to high pressures. In

*For Mr. Milne's biography and photograph, please see p. 64 of the March-April 1956 issue of the GENERAL MOTORS ENGINEERING JOURNAL. This paper follows "The Care and Handling of Liquids in Manufacturing Processes" as the conclusion of a 2-part article. Mr. Milne is supervisor of Materials and Processes for the Production Engineering Section of the GM Manufacturing Staff.

he event of failure of a pipe line, hose, or tting containing these flammable fluids, he fluid is sprayed with considerable orce in a finely divided state over a large rea. If the spray comes in contact with source of ignition, it catches fire, resembling a blow torch while burning.

Some of the applications using hydraulic fluids which present this fire hazard nclude die casting machines, welding nachines, welding positioners which place heavy part in the most convenient osition for welding, and forge-bending nachines. Hydraulic fluids are also used or various operating mechanisms around urnaces, such as furnace door actuating nechanisms, pushers, tilting devices, and lectrode positioners.

The physical properties of a liquid to e used as a substitute for a flammable, etroleum-base hydraulic fluid must be arefully specified. Such a substitute nonammable liquid must have essentially he same characteristics as the petroleumase hydraulic fluid it is replacing if atisfactory operation is to be expected. 'he machinery in which the substitute quid is to be used has been designed to perate with a petroleum-base hydraulic uid, and all of the characteristics of the etroleum-base fluid which affect operaion of the machine must be duplicated.

Many considerations must be kept n mind when attempting to substitute non-flammable liquid for a flamnable, petroleum-base hydraulic fluid. 'he properties required of a nonammable liquid for use in hydraulically perated die casting machines will serve s an example of the many considertions involved when such a substitution to be made.

'on-Flammability

The requirement of non-flammability of prime importance as freedom from re hazard is the main objective when ubstituting a liquid for a flammable, etroleum-base fluid. A substitute liquid sed in die casting machines must not upport combustion when sprayed on hot netal at a temperature of 1,500° F. xtreme care must be used when substiuting a water-base non-flammable fluid n a machine used for magnesium die asting. This is due to the possibility of xplosion resulting from contact of the vater or water solutions with the molten nagnesium.

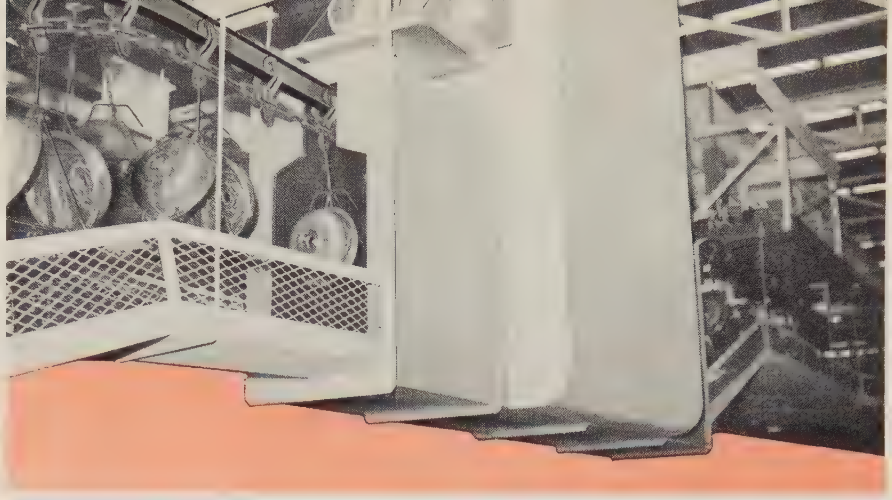


Fig. 2—Many rustproofing materials are supplied as a solution using a highly flammable solvent. Recent developments include a non-flammable type of rust preventive supplied as an emulsion of the rustproofing materials in water. One application of this non-flammable rust preventive is in providing light-duty rust protection to the automatic transmission housings shown entering an evaporator following application of the rustproofing material. As the parts pass through the evaporator, an emulsifying agent used in the rustproofer evaporates and the protective rust preventive film dries on the part. Removal of the emulsifying agent by evaporation prevents re-emulsification of the rust preventive in the event of future contact with water.

Toxicity

A second requirement for a substitute liquid is that it be non-toxic in any state. The liquid, therefore, should not be injurious to health when in the liquid state nor should its vapor given off during normal operation be injurious. Also, the decomposition products of the liquid when exposed to hot metal or open flame should not be toxic. Protection of life and property by eliminating the flammable nature of a liquid must be coupled with the assurance that personnel will not be exposed to an equal hazard from poisoning by toxic liquids or gases. For this reason, chlorinated products are usually not considered desirable as substitute liquids for hydraulic fluids which may be exposed to extremely hot metal. It has been shown that the decomposition products of chlorinated carbon compounds are frequently highly toxic and may include the poisonous gas phosgene.

Lubricity

The smooth functioning of hydraulically operated equipment (Fig. 1) depends to a large degree on the lubricating quality of the fluid it uses. The liquid to be used as a substitute for a petroleumbase hydraulic fluid, therefore, should have a high degree of lubricity. Lack of this quality will result in excessive wear of operating parts, such as in hydraulic pumps which circulate the fluid through the system at high pressure.

Effect on Packings

The liquid used as a substitute for a hydraulic fluid should have no harmful effect on packing materials now in use. If this cannot be done, the fluid should then be compatible with packing materials and gaskets easily obtained from normal sources.

Compatibility

The substitute liquid for a hydraulic fluid should be compatible with those petroleum-base fluids already in use and also with other proposed non-flammable liquids. This property prevents any difficulty due to the formation of heavy or waxy reaction products. Such reaction products might cause malfunctioning of the machines in case of accidental mixing with fluids in the machine. As an example, gummy by-products resulting from mixtures of liquids which do not meet compatibility requirements cause plugging of the filters and resulting starvation of hydraulic pumps.

Viscosity

The viscosity of a non-flammable substitute liquid should compare with those petroleum-base fluids now in use over the range of temperatures commonly experienced. A substitute liquid having desirable viscosity properties will minimize difficulties due to pressure losses from pipe line friction and eliminate sluggish operation.

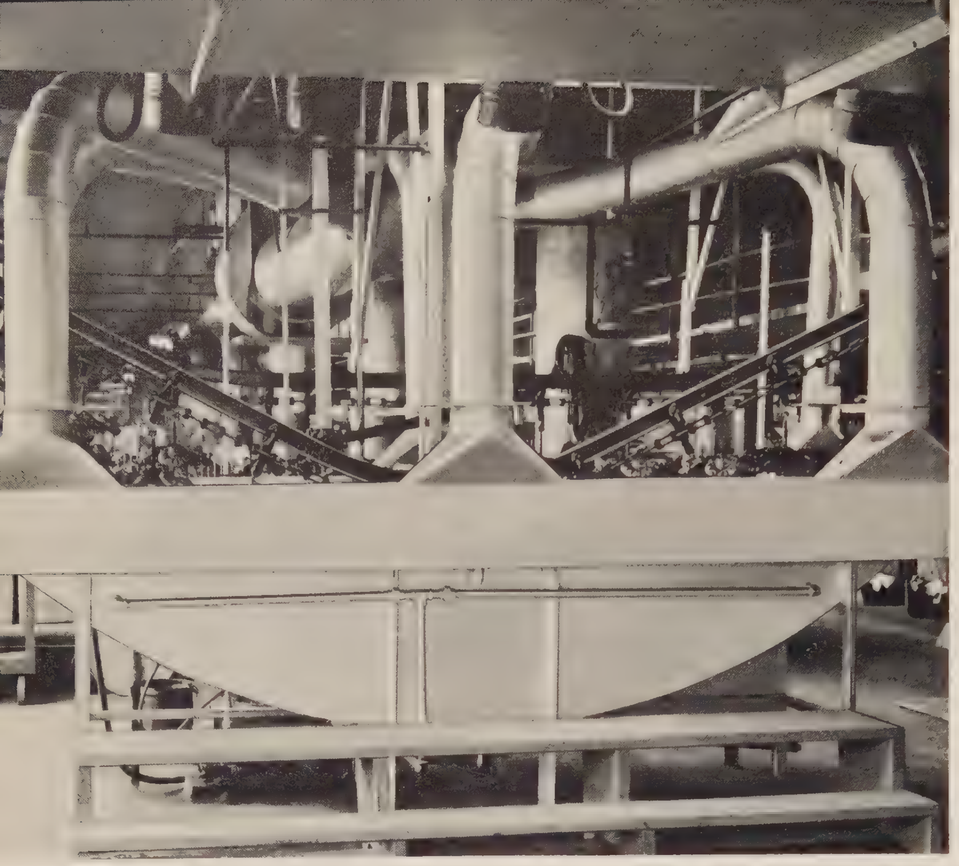


Fig. 3—The development of a paint using water as the thinner is one method in which the normally hazardous nature of painting operations has been eliminated. Shown in the foreground is a dip tank which contains the non-flammable paint and through which parts being painted are moved by a conveyor system. Application of paint by this method eliminates the necessity for careful hooding and installation of automatic fire extinguishing equipment.

Viscosity Index

Satisfactory operation of hydraulically operated machines at varying temperatures calls for a substitute non-flammable liquid to have a high viscosity index. This means that its viscosity will change only slightly with changing temperature.

Specific Gravity

The specific gravity of a substitute non-flammable liquid should be somewhat near that of the petroleum-base hydraulic fluid it is to replace in order to minimize inertia effects in the liquid. Inertia effects may be reduced by installation of a larger diameter pipe for hydraulic pump intake lines. Where certain water-base, non-flammable hydraulic fluids are to be used, the size of the pump intake pipe should be increased to minimize pump cavitation which causes excessive wear in a short period of time.

Corrosion

The substitute non-flammable liquid should be resistant to hydrolysis when in contact with water, which is present to some degree in hydraulic systems. Hydrolysis of certain fluids proposed as non-flammable liquids, especially the ester bases, will result in acid formation causing corrosion of the equipment. The substitute liquid should not corrode non-ferrous metals nor any material used in machine construction.

Hydraulic fluid reservoirs in many machines are painted to protect the metal from corrosion. The possibility of corrosion of the reservoir above the liquid line, resulting from the removal of this protective paint coating, can be controlled by the addition of a vapor-phase corrosion inhibitor, such as di-isopropyl amine nitrate.

Effect on Paint

Many non-flammable hydraulic fluids are very efficient paint removers and may remove paint coatings from the inside surfaces of the reservoir. Loosening of patches or "skins" of paint will not only result in corrosion of the reservoir but in plugging of filters as these patches of paint circulate through the hydraulic system. Any attendant malfunctioning of equipment entails hazard to the operator. Thus, the non-flammable liquid substitute should not affect the paint film to any greater extent than the petroleum-base fluids.

Stability

The non-flammable liquid substitute should not break down when subjected to high temperatures. If break-down occurs, tars, gums, or acids will form. Also, the liquid will separate into various immiscible components.

Compressibility

The non-flammable liquid substitute should be no more compressible than the petroleum-base fluid it is to replace so that its response to the application of energy will be immediate and positive.

Demulsibility

Water should separate from the non-flammable liquid substitute easily and quickly. This property avoids the formation of emulsions which may affect equipment operation.

Foaming

A non-flammable liquid substitute which foams easily has a detrimental effect on hydraulic pump life. The non-flammable liquid should compare favorably with the petroleum-base hydraulic fluid it is to replace in its capacity to absorb air and in freedom from foaming. Foaming also may cause trouble with hydraulic pump intake filters, particularly where all of the original petroleum-base fluid was not removed before addition of a substitute, non-flammable liquid.

Cost

In general, synthetic, non-flammable hydraulic fluids are considerably more expensive than the standard petroleum-base types. This, of course, is a decided disadvantage although in many cases the additional cost for non-flammable fluids is justified in order to secure added assurance against fire. Personnel safety is of prime importance, and cost should be of minor consideration when selecting non-flammable liquids. In cases where hydraulic systems operate with high leakage rates, the high cost involved in the use of non-flammable hydraulic fluids will make better maintenance and housekeeping around the equipment a necessity. Better maintenance of equipment, in turn, pays for itself in providing safer working conditions and better operation of machines.

Types of Non-Flammable Hydraulic Fluids

The description of the characteristics equired of a non-flammable liquid inended to replace a petroleum-base fluid n a hydraulic system has been discussed n detail to give some idea of the probems involved in making such a substiution. It is no simple matter to determine hat a non-flammable liquid can be used uccessfully as a replacement in a hyraulic system. Long series of evaluation ests are necessary both in the laboratory nd on the type of equipment for which he non-flammable liquid is designed. At he present time no liquid on the market neets every required property. Each iquid has its drawbacks, but in a few ases the other qualities of the liquid nake it usable as a replacement for the lammable, petroleum-base hydraulic luids.

Three basic types of non-flammable iquids are available for hydraulic sysems at present. These may be classified s: (a) oil-in-water emulsions, (b) waterase solutions, and (c) organic liquids.

The oil-in-water emulsion type of nonlammable liquid is usually used in pproximately 10 per cent concentration or equipment which does not require ise of complex hydraulic valves or vaneype pumps or which have clearances onsiderably greater than those required or flammable petroleum-base fluids. Dil-in-water emulsions have been used atisfactorily in hydraulically actuated quipment, such as baling machines used o compress scrap metal into blocks. One General Motors Division is using oil-invater emulsions in die casting machines vhich have been redesigned to permit he clearances required with this type of ion-flammable liquid.

The second basic type of non-flamnable liquid—water-base solutions—is enerally composed of the glycols, such s ethylene glycol and certain polylkylene glycols together with other additives intended to modify viscosity and add ubricity to the liquid. Other additives re necessary to reduce the liquid's corosive properties, inhibit foaming, and mprove stability and viscosity.

The third type of non-flammable iquid, described as being "organic," ncludes phosphate esters and chloriated products together with the usual dditives for improvement of operating roperties. Tricresyl phosphate has been ised as a non-flammable liquid in the past but gave considerable trouble with poor lubricity until modified with additives to improve this characteristic. A chlorinated diphenyl also has been used for this purpose. It is considered to be more toxic than other compounds available, however, and has undesirable viscosity index properties. Most of the materials in this group being used today are in the phosphate ester classification.

The oil-in-water emulsion and waterbase solution types of non-flammable liquids are actually flammable materials suspended or dissolved in water. Because their fire resistant properties depend on the concentration of water present, evaporation of this water during use can result in a flammable liquid. Use of these types, therefore, involves careful control of water content and constant inspection to assure that the proper amount of water is present at all times.

Use of Non-Flammable Liquids in Machining Operations

The cutting of metal during the manufacture of various parts is usually accompanied by the generation of a large quantity of heat. A cooling fluid must, therefore, be distributed over the surface being cut to remove this heat and to eliminate distortion, excessive tool wear, and undesirable surface finishes.

The fluids used to cool the parts and to lubricate the cutting tool as it removes metal are usually petroleum-base oils used either as a straight oil or in the form of an emulsion. While most of these petroleum-base oils have relatively high flash points and are not likely to be the immediate cause of fire, their use in many machining operations throughout the plant provides a large reservoir of fuel on which a fire started from some other source may feed and spread.

Over the last few years many GM Divisions have conducted experiments on the possibility of substituting water emulsions for the straight petroleum-base cutting oils. The experiments indicated that there are several machining operations where such a substitution is possible. One Division reports that their entire hobbing and gear cutting operations are now conducted with soluble oil emulsions rather than with the straight mineral oils used previously.

Following a cutting operation, it is frequently necessary to clean the part being machined to permit satisfactory inspection or some other subsequent manufacturing operation. Where heavy (high viscosity) petroleum-base cutting oils are used, it has been the practice to remove these oils by dipping or washing in a petroleum-base solvent usually of relatively low flash point. This constitutes a fire hazard at every machining operation using this cleaning process. To overcome this situation, one GM Division has substituted an emulsifiable oil in a gear lapping operation which previously used a heavy petroleum cutting oil. Due to this substitution the parts are now washed in a water soluble cleaner where previously a solvent cleaner was used. This has reduced fire hazard not only in the gear lapping operation but also in the subsequent cleaning operation.

Metal Cleaners

A metal cleaning operation may vary from a simple rinse to remove heavy material which might interfere with inspection of the part being manufactured to an intensive cleaning intended to remove every particle of foreign material from the metal surface before application of the final finish. The selection of a cleaning agent is frequently dictated by the requirements of the next step in the manufacturing operation.

Some of the properties to consider when substituting a non-flammable for a flammable cleaning agent are the ability of the cleaner to remove the particular soil involved, drying time required, what health hazard might result from use of the cleaning agent, and, of course, its cost. Expensive and highly volatile cleaners may prove impractical for any operations other than those in which vapor recovery is practiced. Within these requirements, however, it is frequently possible to substitute a non-flammable type of cleaner for one which has flammable properties.

In some GM Divisions flammable solvents were used to clean sheet metal before a painting operation. Some of these Divisions have found that a phosphoric acid base cleaning material, which produced an iron phosphate coating on the surface of the metal, was a satisfactory substitute for the solvents formerly used and provided a better base for paint.

Some Divisions manufacturing fractional-horsepower electric motors have used naphtha to clean motor components. Substitution of a chlorinated product, 1, 1, 1, trichloroethane (methyl chloroform), which contains an inhibitor

against attack on aluminum proved to be satisfactory for this operation. Water soluble cleaners did not produce the results needed for this particular cleaning operation.

Mineral spirits used in power washers to clean engine blocks at room temperature were replaced at one Division by a cold water soluble cleaning compound which not only eliminated any potential hazard but also resulted in a savings in material cost. In a like manner, an extremely hazardous naphtha cleaner used by one GM Division for cleaning stators and rotors used in refrigeration compressor drive motors was replaced with methyl chloroform. For this particular cleaning operation consideration had to be given to the effect of residuals from cleaners on the operation of the parts in the refrigerator. The new cleaner not only had to do the job but also had to meet the approval of the organization assembling the parts.

In almost every GM Division investigations are going on to determine how flammable solvent cleaners can be replaced with either water soluble emulsions or non-flammable chlorinated cleaners. Most Divisions already have found places where substitutions can be made in certain cleaning operations without interfering with the subsequent quality of the product.

Asphalt Sound Deadeners

Undercoating and sound deadening materials are frequently required in the building of automobiles, passenger coaches, and railroad equipment. In the past, solvent cutback asphalts (asphalts dissolved in or thinned with a petroleum solvent base) have been used as the base for most of these products. On the experimental lightweight General Motors Aerotrain the solvent cutback asphaltic undercoating material was replaced with a water-emulsion asphaltic undercoating.

The solvent cutback asphalt deadener is standard for use in passenger highway coach roofs. In one coach assembly operation, however, this material was changed to a water-emulsion type of deadener because of the close proximity of spot welding equipment and the danger of flying sparks igniting solvent fumes from the former material.

Rustproofing Materials

Rustproofing materials provide protection against rusting for various well-defined periods of time and under specified conditions of exposure. For example, heavy duty rust protection is given a part which will be stored or transported for considerable periods of time with little protection from the elements. Medium rust protection is given to a part exposed to less severe conditions and protected by other mechanical means. Light rust protection is given to parts intended for in-plant storage between manufacturing operations or to parts maintained in a bank for future use in production.

Most of the rustproofing materials in use are highly flammable. Some materials make use of solvents which have a low flash point. Where a low flash point rustproofing material is used the fire hazard is great, and suitable steps must be taken to equip the plant to handle the hazard.

A few years ago an intensive developmental program produced a water-emulsion type of rust preventive for light-duty application. In this type of rust preventive, the ingredients of the former, solvent cutback type were placed in the form of an emulsion. An emulsifying agent was used which evaporated as the protective film dried. This type of emulsifying agent was necessary to prevent re-emulsification of the rust preventive on further contact with water. Several GM Divisions now make use of this type of light-duty rust preventive (Fig. 2).

At the present time no satisfactory water-emulsion rust preventive has been found to provide the protection needed for medium or heavy-duty exposure. This problem is being investigated by rust preventive manufacturers, and samples of the products they develop are under constant testing in Divisional laboratories and by the General Motors Research Staff.

Although emulsification of the rust preventive formerly supplied as a solvent cutback sounds rather easy, certain very definite requirements are necessary for an emulsion to be used for this purpose. As an example of the requirements an emulsion must meet, the following simple screening checks are performed by the Chemistry Department of the GM Research Staff before conducting actual rustproofing tests:

- The emulsion must not be reversible, and the emulsifying agent must evaporate so that the film will not re-emulsify when exposed to moisture or water; an emulsifier of th[e] morpholine type is an example
- The material must be easily emulsifiable and should not require separate mixing equipment; this requirement eliminates most paste materials
- Prior to mixing with water, th[e] flash point of the material, a[s] received, should be between 325° [F] and 350° F
- The viscosity of the material, a[s] received, should be between 40[0] seconds and 500 seconds when measured with a Saybolt Universal Viscosimeter at 100° F
- The emulsion must not form a[n] insoluble skin on cooling as thi[s] would be removed quickly by th[e] first *drag out* thereby lowering th[e] total solids; (*drag out* is the liqui[d] which clings to or is trapped in [a] part as it emerges from the solution
- The emulsion must have good wetting characteristics and should no[t] require a water break-free surfac[e] before application
- The emulsion must be stable an[d] should not depend on agitation fo[r] emulsion retention
- The emulsion must not foam excessively
- The emulsion must be sufficientl[y] tolerant of calcium so that most ta[p] waters may be used without breakdown
- The emulsion must not be too sensitive to acid; a pH of 1 should b[e] tolerated without separation
- The emulsion must not be too sensitive to carry-over of liquid fro[m] alkali cleaning solutions
- The emulsion should be capable o[f] withstanding a temperature of 170[°] F for long periods of time withou[t] excessive breakdown
- The emulsion should prevent corrosion due to fingerprints left on part[s] before application of the rust preventive
- The emulsion should give a "thi[n] oil film" type of protection (light duty corrosion protection)
- The film of the emulsion should b[e] easily removed by standard cleaner[s]
- The emulsion should contain n[o] silicones; (silicones are extremel[y] hard to remove by standard cleaning operations, and their presenc[e] may result in unsatisfactory adhesion of paint films applied to th[e]

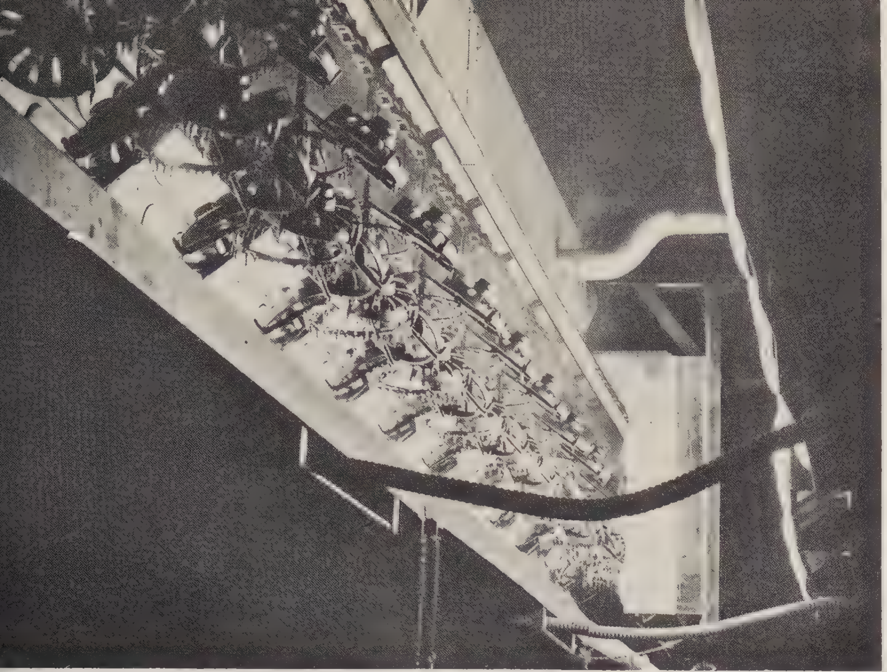


Fig. 4—Motor end-frames, painted in a dip tank (Fig. 3) containing a non-flammable paint using water as the thinner, are passed through the infrared oven shown. As the frames pass through the oven, the water is evaporated from the emulsion and the paint is left on the frame. The precautions necessary in the usual paint drying oven to prevent ignition of solvents evaporated from the paint film are not needed in this process.

part in some subsequent finishing operation)

- The cost of the emulsion should be reasonable.

Stretcher Rolling Operations

In a stretcher rolling operation, coiled steel is straightened by being passed through a series of rolls. During this straightening operation, liquids such as kerosene are frequently used to clean and lubricate the steel as it passes through the rolls.

One GM Division found that an oil emulsion could be substituted for the kerosene formerly used. When this was done, however, splashing of the water into the operating parts of electrical control switches caused a short circuit and necessitated relocation of the switches. In other parts of the stretcher rolling equipment, shielding or the use of closed electrical switches became necessary to prevent damage from the "soluble" oil emulsion splashed over the equipment.

Painting Operations

Ordinarily, a painting operation is looked upon as a hazardous activity due to the normally flammable nature of paints. To lessen this hazard, advances have been made in developing non-flammable painting systems.

Development of non-flammable painting systems has proceeded along two lines. The first of these is the development of a paint which uses non-flammable trichloroethylene as the solvent and vehicle. At present, application of this type of paint is confined to dipping operations performed in tanks which are similar to degreasers in appearance. The parts to be painted are dipped in the tank while still hot, and the evaporating trichloroethylene is condensed as the part moves through the cold zone of the dip tank. The condensed trichloroethylene then returns to the paint system and is not lost by evaporation.

At the present time the application of the non-flammable trichloroethylene type of coating is confined to parts which do not require top quality appearance characteristics—for example, concealed parts such as window lifting mechanisms or various parts which are installed under the hood of an automobile and are normally out of sight.

A second approach to the development of non-flammable paints concerns preparation of the paint as a water emulsion. The paint as received from the manufacturer is simply diluted with water, placed in an open dip tank (Fig. 3), and used with a minimum of fire protection devices. The parts, after passing through the dip tank, proceed through ovens (Fig. 4) which evaporate the water from the emulsion, leaving a paint film behind. At present, the availability of water-emulsion paints in a variety of colors is limited.

Quenching of Heat Treated Metals

One possible source of fire in manufacturing operations results from ignition of the oils used in quenching heat treated metals. Under some circumstances quench tanks catch fire and produce an extremely hazardous condition. Experiments are under way on non-flammable water solutions containing various resinous materials to be used as substitutes for the flammable, petroleum-base quenching oils now in use. These resinous materials are still in the developmental stage, but continued investigation will undoubtedly develop satisfactory non-flammable quenching materials in the future.

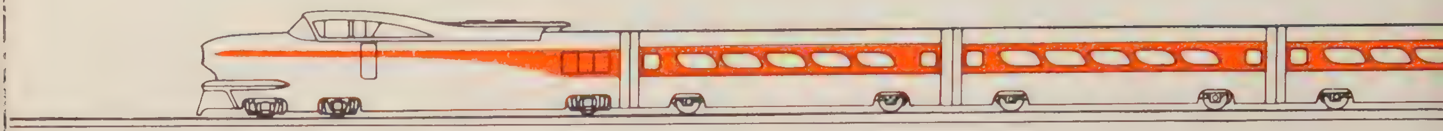
Summary

In the past few years notable advancements have been made in developing non-flammable liquids as suitable replacements for certain flammable liquids used as hydraulic fluids, metal cutting and cleaning liquids, sound deadening and rustproofing materials, paints, and quenching oils. Non-flammable oil-in-water emulsions, water-base solutions, and organic liquids have been successfully used as substitutes for flammable, petroleum-base hydraulic fluids. Water emulsions have been substituted for petroleum-base cutting oils. Water soluble emulsions and non-flammable chlorinated liquids are employed as replacements for flammable solvent metal cleaners.

Many steps can be taken to provide protection to the plant and its personnel by redesigning equipment using flammable liquids or by extensive use of fire extinguishing devices. The fact still remains, however, that a flammable liquid will burn and a non-flammable liquid will not.

Before production use of non-flammable liquid substitutes can be accomplished, evaluation tests must be performed on the specific non-flammable liquid under consideration. It is not simply a matter of substituting a liquid which does not burn for one which does. The liquid's non-burning characteristics, of course, are important. But also of importance is the ability of the liquid to effectively perform the same function of the flammable liquid it is replacing without seriously affecting the equipment in which it is to be used or the quality of the manufactured product.

A Progress Report on the Development of the General Motors Aerotrain



Railroad interest in completely new forms of passenger equipment stems from the huge deficit the industry is experiencing each year in its passenger operations. The railroads were interested in the suggestions which General Motors might have for new passenger equipment that would: reduce equipment investment, reduce operating and maintenance costs, lower center of gravity and increase average speed, improve riding comfort, and make possible lower fares to attract greater passenger traffic. The broad objectives for such a train were determined by conversations between various railroad presidents and representatives of General Motors Electro-Motive Division. Because of its experience in the design and building of power plants and car structures for gasoline-electric rail cars and Diesel locomotives, Electro-Motive was in a unique position to make a substantial contribution to the solution of the problem, and the Aerotrain project was undertaken.

General Motors Aerotrain (Fig. 1) was conceived and developed in answer to the need for low-cost, quick, and comfortable passenger rail transportation. It was decided at the outset that consideration would be given, wherever possible, to the use of standard components already in mass production which would, thus, be more economical and of proven dependability.

Fig. 1—The experimental Aerotrain, consisting of the locomotive and 10 passenger cars, is designed to function as an integrated unit. Its streamlined body styling, together with railrading "firsts" in the design and application of its mechanical components, is aimed at improving performance while reducing manufacturing and maintenance costs. This saving, along with its features of styling, safety, and comfort, can then be passed on to the railroad passenger.

In order to make a significant reduction in initial cost, bringing it in line with that of competitive highway equipment, it was realized that cars for the new train would have to be built for about half the cost of conventional railroad equipment.

Since General Motors already was building highway passenger carriers in this cost range, the first idea was to put an intercity highway coach body o railroad wheels. This led to the concep of a railway coach body made up o highway coach body components mount ed on a strong, railroad-type underfram (Fig. 2). The highway coach body wa widened 18 in. to provide more com fortable seating space and a wider aisl The driver and engine compartmen were replaced by vestibules containin side entrances at the front-end and wash room and service facilities at the rear-en

Each car was designed as an inde pendent unit, providing flexibility t meet individual railroad requirement in contrast to articulated trains in whic 1 truck supports the ends of 2 cars. 4-wheel under-carriage was chosen t keep the car weight to a minimum.

The seat level in the Aerotrain wa made as high as practical, consistent wit the use of the highway coach body an the overall height of the train. This wa advantageous for several reasons: (a) fitted in with the use of the highwa coach body construction, (b) it improve visibility for the passenger, and (c) achieved a high degree of passenge safety in event of collision from the side

In determining passenger capacit consideration was given to the requir ments of washroom and service facilitie the standard sizes of auxiliary equipmen particularly air conditioning; the conve tional seating arrangement determine by the highway coach body design, whic made desirable even increments of 8 pa sengers; and the increase in car weig per passenger as the length of the car i creases. The most practical choice wa a capacity of 40 passengers.

Since the new train was to be design to stimulate rail travel by making possib lower fares, the characteristics of i creased performance, simplicity, a

By B. B. BROWNELL
and WILLIAM H. HARVEY
Electro-Motive Division

A problem in comfortable, safe, and speedy passenger rail service at lower cost

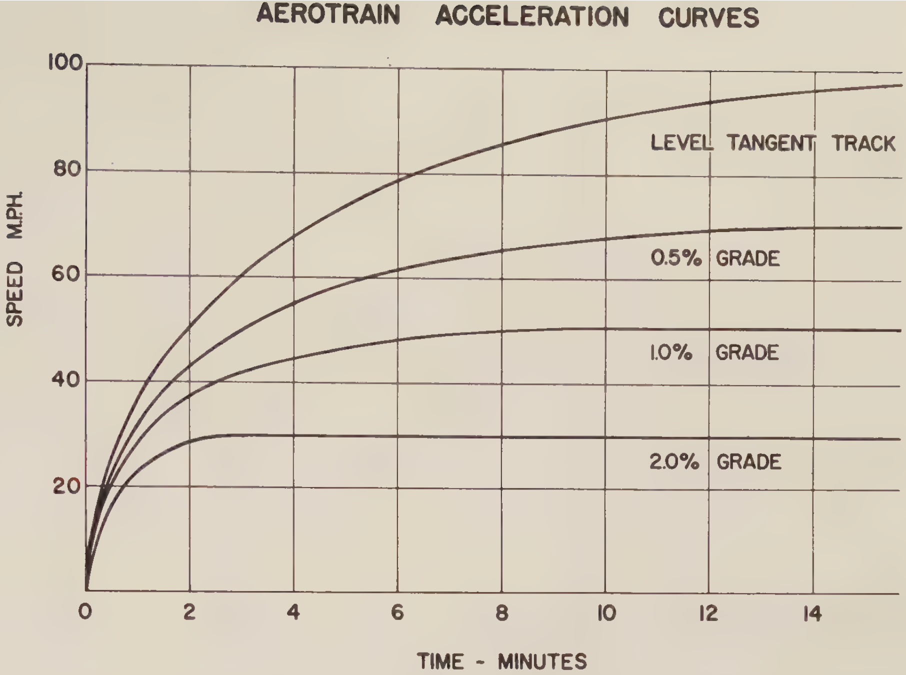


Fig. 3—Calculated acceleration curves for the Aerotrain on various grades using the General Motors 12-cylinder 567C Diesel engine delivering 1,200 hp for traction are shown above. The acceleration curves indicated that the single locomotive unit needed to haul the 10-coach, 400-passenger train would be, in effect, half of a model E9 Diesel (standard General Motors 2,400 hp Diesel passenger locomotive unit powered by 2, 12-cylinder, 567C engines).

economy consistent with passenger comfort were set as keynotes for the train's facilities and equipment.

Three overall objectives were established as guides in designing the new train:

(a) The locomotive and 10 cars were to be held as near as possible to 600,000 lb gross weight

(b) Both investment and operating costs of the new train were to be reduced—the coaches to be designed to be built for approximately half the cost of conventional railroad equipment

(c) The styling was to be such as to dramatize the train as an entirely new concept in passenger train equipment.

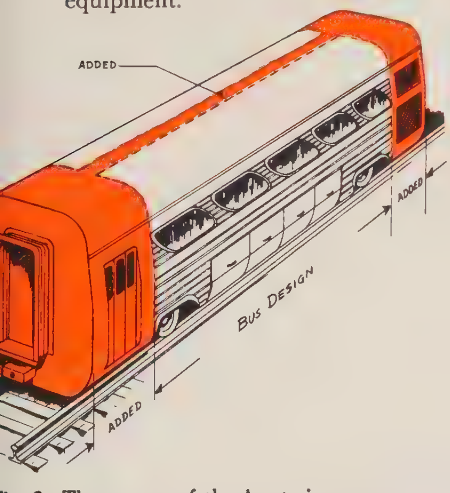


Fig. 2—The concept of the Aerotrain passenger car is that of a highway coach body, widened 18 in., with front entrance and rear service vestibules. It is mounted on a strong, railroad-type underframe.

Integrated Design of the Aerotrain

In approaching the design of the Aerotrain, Electro-Motive's Engineering Department and the GM Styling Staff had a unique opportunity. Here, for the first time, was an opportunity to design a train in which locomotive and cars could be treated as integral parts of the whole to obtain the optimum in flexibility and economy. The size of the Diesel motive-power engine, the size of the auxiliary Diesel engines, and the size and weight of the cars, for example, were determined by the contribution each makes to the complete unit from the standpoint of performance, initial cost, operating characteristics, maintenance and repair costs, and safety.

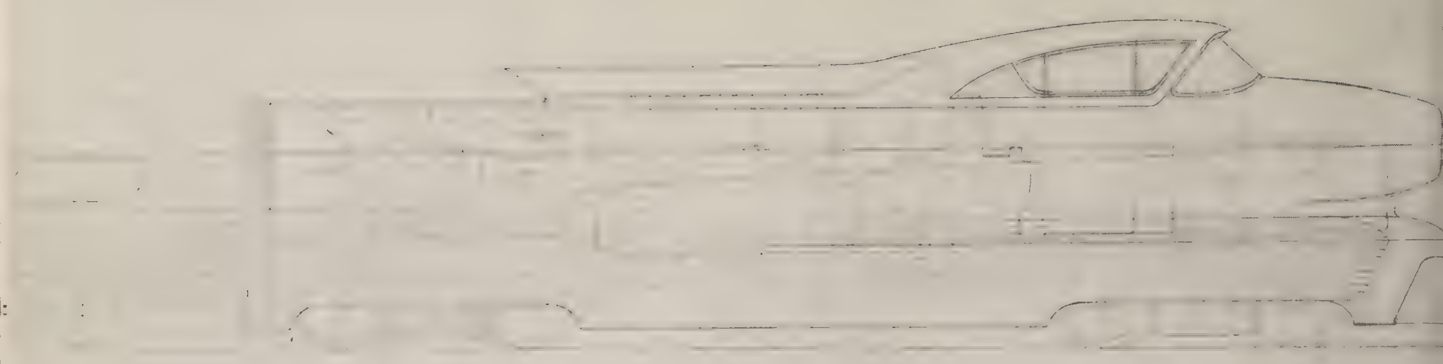
The design of a complete train whose locomotive and cars were to be used exclusively as a unit meant that many important engineering improvements could be made for the first time. For example, an auxiliary power source located in the locomotive supplies current not only for train lighting, but for individual heating and air conditioning units in each car as well, eliminating the problem of head-end steam heating with the disadvantages of long steam and water supply lines. The elimination of steam lines makes possible the use of an automatic coupler on the cars which makes all necessary (electrical and air) connections as the cars are coupled. Freedom from the problems related to equipment which must be interchangeable permitted the design of an entirely new air brake system with substantial reductions in both cost and weight as fundamental objectives.

Locomotive Design

Since total weight of the complete train was to be approximately 600,000 lb, design of the Aerotrain locomotive was started by determining the *minimum* horsepower needed to pull this weight at a maximum speed of 102 mph. The General Motors 12-cylinder 567C Diesel engine delivering 1,200 hp was found adequate to meet the performance requirements of the train when acceleration curves were calculated (Fig. 3). It was also determined that 2 Electro-Motive D-37 traction motors could transmit enough power to meet load requirements which permitted the design of the rear locomotive truck as a single, idler axle and, thus, contributed to overall weight reduction.

The Aerotrain locomotive features a completely new interior arrangement of components (Fig. 4), as well as radically new exterior styling, consisting of lightgauge sheet steel welded over a structural framework, to blend with the new lightweight Aerotrain cars.

The underframe consists of 2 "fishbelly" I-beam center sills which serve as



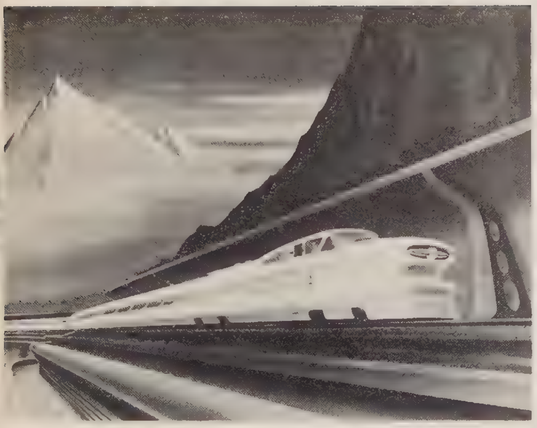
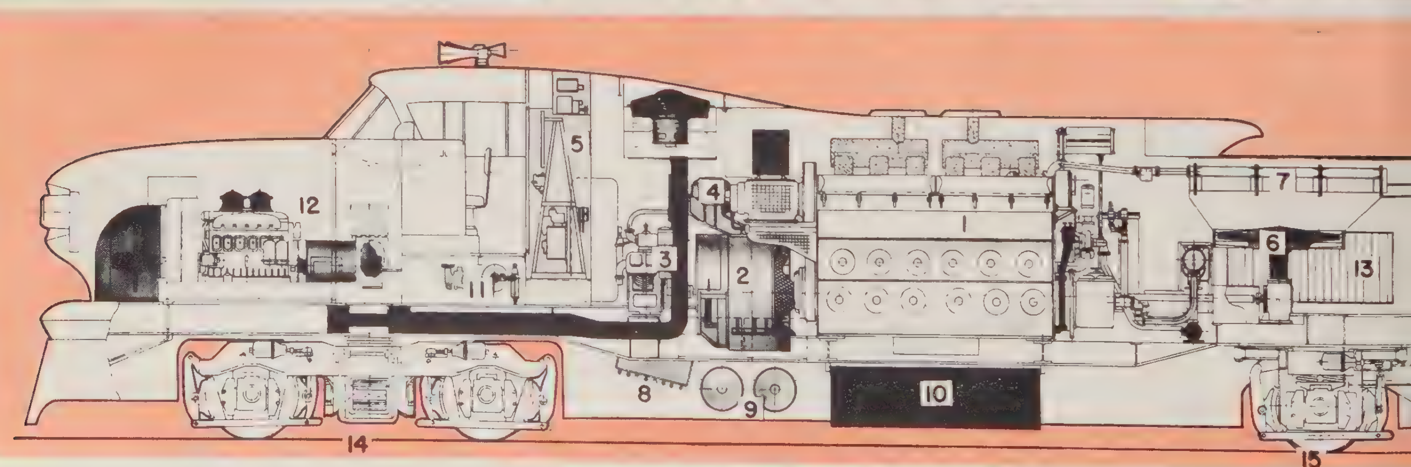


Fig. 4—Shown across the top of the page is one of the first freehand sketches made by GM stylists and Electro-Motive engineers to establish the styling and engineering goals of the Aerotrain. From such sketches, renderings (above) were made to provide a more vivid picture of appearance features. A clay model (right) and ⅛-scale layouts served as the bases for the full-scale drawings used in building the train. An elevation view of the locomotive (below) shows the new arrangement of components and several improvements in control schemes. Construction followed established Electro-Motive practices and used as many proven components as was feasible.



1 ENGINE - EMD MODEL 12-567C
2 GENERATOR - EMD MODEL D15E
3 AIR COMPRESSOR
4 AUX. GENERATOR
5 ELECTRICAL CONTROL CABINET
6 COOLING FAN
7 RADIATORS
8 COMPRESSOR AFTER COOLER
9 MAIN AIR RESERVOIR
10 FUEL TANK
11 AIR BRAKE EQUIPMENT
12 GENERATING SET - MODEL
13 ENGINE COOLING AIR INTA
14 POWER TRUCK
15 IDLER TRUCK

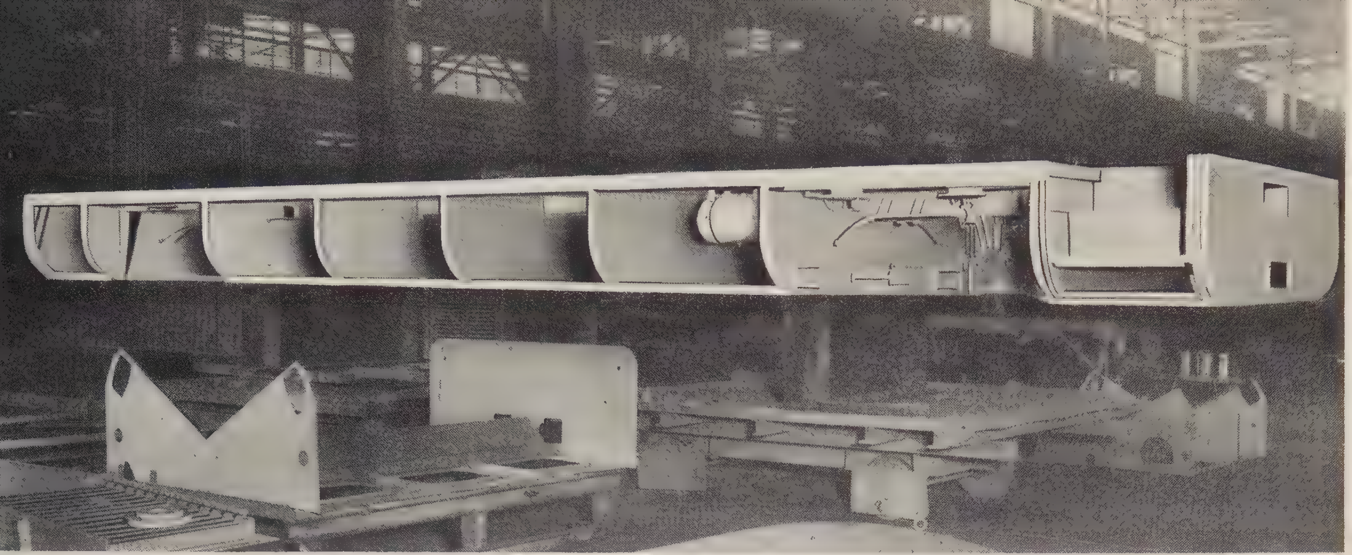


Fig. 5—The strong, steel car underframe provides support out to the sides of the passenger car. Under-floor compartments provide spacefor heavy baggage and housing of the individual heating and air conditioning units and other equipment.

main supporting members for the car body, cab, and equipment. Two side sills, supported by the center sills, partially support the cab and car body framing and the skirt arrangements. Coupler pockets are welded to built-up platform constructions between the center sills. Jacking pads are provided for lifting the locomotive. The complete underframe assembly is of all-welded construction.

The main motive-power equipment consists of the 12-567C Diesel engine and a standard Electro-Motive D-15E d-c generator, located in the depressed, "fishbelly" section of the under-frame to lower the center of gravity, and the 2 Electro-Motive D-37 traction motors, located on the front 2-axle truck. Major components between the Diesel power package and the control cab are the air compressor, dynamic brake hatch, and the electrical control cabinet. The air brake equipment is mounted beneath the cab floor. Cooling equipment is located at the rear of the locomotive. In the nose of the locomotive are mounted 2 auxiliary Diesel power units used to supply electric power for train lighting, heating, and air conditioning. These are standard units consisting of 6-cylinder, Model 6-71 Detroit Diesel engines powering 440-v, 3-phase, 60-cycle Delco a-c generators.

Several improvements in control schemes and devices have been incorporated in the Aerotrain locomotive. The transition control relay, a device similar to an automobile gear shift and which makes possible the re-connecting of traction motors, is modified so that it tends to keep the power higher during very rapid acceleration and more effectively loads the power plant in areas of moderate- to high-speed operation at reduced throttle. Motor cut-out control has been improved so that, with 1 traction motor cut out, practically full power capacity of the other motor can be utilized over a relatively wide speed range, limiting current at the same time to a reasonable value for starting and accelerating

Car Design

In designing the cars, Electro-Motive engineers started with a strong, steel underframe (Fig. 5). Mounted on this frame is the car body, a design based on the standard GM intercity highway coach body. The car is 40 ft long, 9 ft, 6 in. wide, and 10 ft, 9 in. high (Fig. 6). Height of the floor is 43 in. above the rail, nearly as high as that of conventional railroad coaches. The center of gravity, however, is only 45 in. above the rail, which approximates that of other lightweight trains. The front entrances will serve either high or low station platforms (Fig. 7). At the rear end of the car is a service section with a lavatory and a snack bar. Electropneumatically operated, 2-section sliding doors, controlled and made safe by sensitive door edges, are located in the bulkheads of the front- and rear-ends. Inner and outer diaphragms, applied to each end of the car, provide protection to passengers passing between cars.

The passenger compartment (Fig. 8) contains 40 modern, reclining-type seats spaced 35 in. apart. Package racks above the seats provide approximately 140 cu ft of storage space with room for heavy luggage provided in special compartments located under the car floor. A row of fluorescent lights runs the length of the car over the center aisle. Aisle lights are also provided on the seats, and reading lights for each seat are located under the package racks.

The absence of ornamentation in the interior design has reduced the cleaning problem to a minimum. Interior finish is of attractive and durable materials requiring a minimum of painting and other maintenance, thereby reducing the overall cost of up-keep.

The structure of the new cars (Fig. 9) represents a new concept in railroad passenger car design. One of the important factors in the losses railroads suffer on passenger service is the drain of repairing cars periodically and their complete overhaul approximately every 7 years in order to present habitable and attractive public transportation. In contrast to the conventional-type car, the new Aerotrain coaches combine a replaceable body, which is low in initial cost compared to conventional passenger cars, with a sturdy undercarriage made to last many years with a minimum of maintenance. When the Aerotrain coaches require overhauling, the old body can be replaced easily with a new one, in which all the modern advances of styling, comfort, and safety are incorporated, at less cost than is now spent refurbishing conventional cars.

The Air-Ride System

To achieve improved riding comfort an "air-ride" suspension system, developed by GMC Truck and Coach Divi-

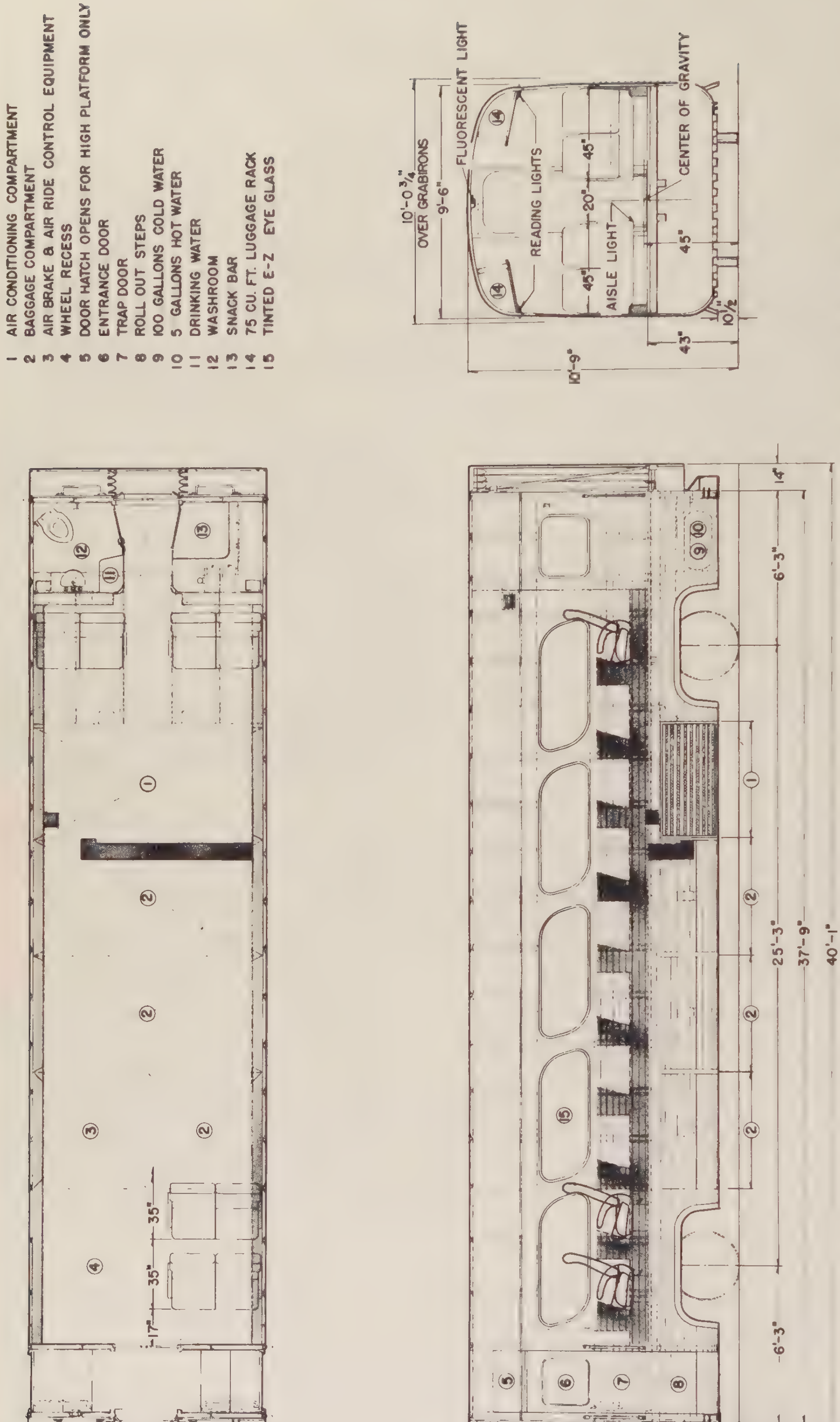


Fig. 6—The 40-passenger car features a center of gravity only 45 in. above the rail while maintaining "high-ride" seating for the passengers. An empty car with complete supplies weighs approximately 38,000 lb.

sion, was adapted to railroad use. Thi level-ride control is similar to that use on General Motors highway coaches.

The air-ride system consists basicall of 2 separate charging lines, a signa device, air reservoir and ride-contro devices, and the necessary limit an check valves.

Eight air bellows are mounted 4 o each single-axle truck (Fig. 10) to sup port the car's weight. Initial charging i done by means of the train's main ai supply. A relay air valve connected be tween the charging line and the signa line actuates a warning signal in th locomotive cab whenever the pressur in the bellows falls below a predeter mined pressure. Subsequently, chargin of the air bellows and ride-control device is accomplished through the air reser voir line.

The air pressure in the bellows is con trolled between the upper and lowe limits by the ride-control valves, whic function to hold the height of the ca body above the rail at a constant value admitting or exhausting air in the bel lows as the load on the car is increase or decreased. A hydraulic dashpot i incorporated in the ride-control valve to delay the pneumatic response, allow ing normal movement without constan readjustment of the bellows' air pressures

The Air Conditioning System

Electro-Motive engineers eliminate the need for a steam generator in th locomotive and the trainlined stea supply required with conventional equip ment by designing a unique air con ditioning and heating system which i installed in each Aerotrain car. The sys tem (Fig. 11) includes a 5-ton refrigera tion unit, manufactured by Frigidair Division, with a reheat cycle for de humidification and temperature contro Separate heating units are provided fo cold weather operation.

The system is located in the equipmen compartment in front of the rear whee well on the car undercarriage and ma be manually controlled from a panel i the snack bar compartment of the ca

The conditioned air is distribute through longitudinal ducts along eac side of the car body at the floor line an thence to vertical ducts which dispers the air through openings at the base o the windows. Outlets are provided in th longitudinal ducts for distribution of a over the floor. Make-up air is obtaine

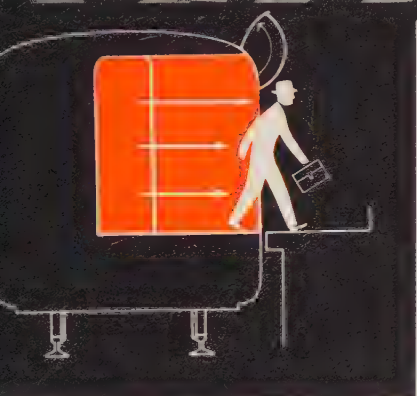


Fig. 7—Each coach has a front-end vestible with entrances on both sides. Doors and steps are arranged so that the entrances will serve stations with either high or low platforms.

through grilles in the roof and is transmitted to the air conditioner through vertical ducts in the rear bulkhead of the passenger compartment. The system has a total air-flow capacity of 2,070 cu ft per min, 20 per cent of which is make-up air.

Heating is supplied as required by a water-to-air heat transfer coil. During the heating cycle, heat is supplied to the water by an 8-kw electric immersion heater of 28,300 Btu-hr capacity. When more heat is required, the entire load is taken over by an oil-fired heater of 150,000 Btu-hr capacity. Car temperature is controlled by a thermostatically modulated bypass valve which varies the flow of hot water through the heat transfer coils as required.

During the cooling cycle, the refrigeration unit runs continuously at full capacity. Temperature control is obtained by reheating the refrigerated air with the same hot water system used in the heating cycle with heat obtained from the hot Freon leaving the compressor by means of a precondenser. Thus, the reheat cycle takes heat removed from the air and replaces it, as necessary, to control the conditioned air temperature. The amount of reheating is controlled by bypassing the water flow as necessary. Thus, the same temperature control thermostat is used for both heating and cooling cycles.

The Air Brake System

Operation of the Aerotrain locomotive and cars as a unit, linked by automatic couplers, permitted simplification of the air brake system, resulting in significant cost and weight savings. Non-metallic, plastic brake shoes were chosen, also reducing cost and weight. These shoes require only one-third the braking force of cast iron shoes to produce a given braking action due to higher friction values and, thus, make possible the use of much smaller brake cylinders.

The arrangement of the air brake system (Fig. 12a) permits operation of 2 to 12 cars in multiple service. A standard locomotive could also haul the Aerotrain in an emergency and maintain adequate air brake control for complete safety. Break-in-two protection is provided in the event that parting of the train occurs.

The 2 principal circuits in the system, trainlined through all the cars, are: the straight air line, which controls the application relay on each car, and the supply line, which supplies air at 110 psi to the application relay and break-

Fig. 8—The modern, reclining passenger seats are rubber-filled with changeable nylon covers, washable head rests, footrests, and ashtrays in the armrests. There are package racks on each side above the seats, and a single row of fluorescent lights over the center of the aisle provides interior light the length of the car. The keynote of the fixtures and design is pleasing simplicity combined with durability.

in-two protection relay. There is also a conventional signal line (not shown in the diagram). The release and application cylinders (Fig. 12b) are mounted on arms of different lengths; when the pressures in each are equal, the brakes are released.

Operation of the control handle in the locomotive allows air pressure to develop in the straight air line, reducing the regulated air pressure which the relay valve supplies to the release cylinders at the rate of 3 psi reduction per 1 psi increase in the straight air pressure. Pressure in the application cylinders and volum reservoir remains the same because of a check valve in the line. Thus, the brake are applied with a force proportional to the pressure differential between the re lease and application cylinders which i dependent upon the reduction made. I case of full application, a valve in th locomotive drops the supply line pressur to zero, operating the break-in-tw features of the locomotive and each car

A full application is in effect 3.7 seconds after movement of the brak valve handle. A service application of 4 psi is in effect within 5 seconds on th tenth car.

Testing the Aerotrain

Stress tests were run on the first ca underframe and shell upper-structure The structure was loaded vertically u to 200 per cent of normal with no indications of abnormally high stress. The ca was also loaded with 600,000 lb buff or compression, load, applied longitudinally on the end of the car, withou showing signs of stress.

Instruments were installed for roa testing, and pick-ups connected to a oscillograph were provided for measurin the vertical deflections between the truck and car body. A gyroscopic instrumen was installed for recording the roll of th car. Three-way ride recorders were use to record lateral and vertical shocks, an a television set with camera focused o the contact point between wheel an rail showed how the car was tracking

Speed tests up to 100 mph were made and subsequent improvements in the ai suspension system and shock absorber greatly improved the car riding qualities

Fig. 9—The car for the new Aerotrain combines a replaceable body with a sturdy undercarriage. When the car's condition requires overhauling, the old body can be replaced with a new one, including all the modern advances, for less money per passenger than is now spent for refurbishing conventional-type cars.

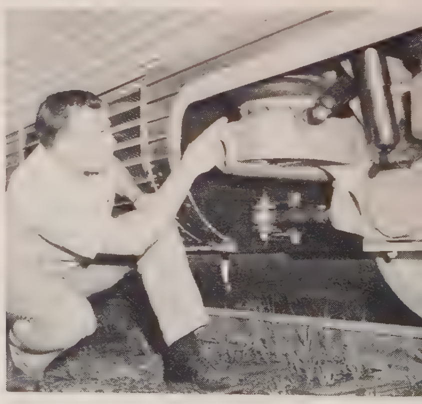
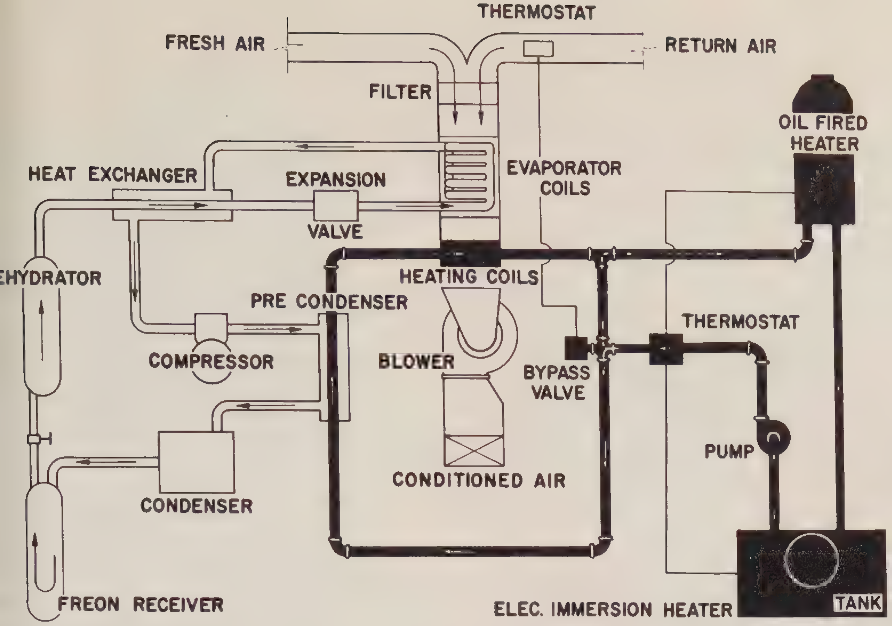
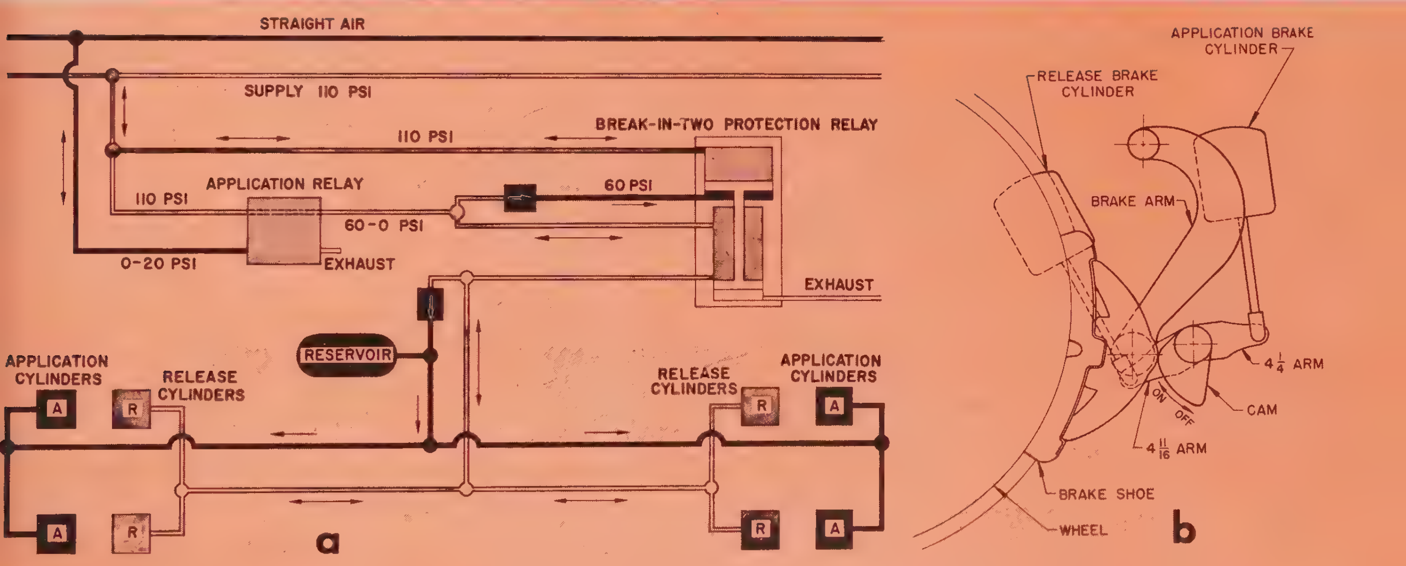


Fig. 10—Eight air bellows, mounted 4 on eac single-axle truck, support the entire weight of th Aerotrain coaches in air-ride suspension. Th bellows are attached to air boxes, built into th underframe of the car, which are charged with a from the train supply line.



ig. 11—A self-contained air conditioning system is installed in each car. Air is obtained through grilles n the car roof and transmitted to the air conditioning unit through vertical ducts in the rear bulkhead of the passenger compartment. Conditioned air is heated, as required, by a water-to-air heat transfer coil, and temperature control is obtained by reheating the refrigerated air with the same hot water system used in the heating cycle. The amount of reheating is controlled by bypassing the water flow as necessary, and the same temperature control thermostat serves for both heating and cooling cycles. The air flow capacity is 2,070 cu ft per min.



ig. 12—The air brake system features simplicity with rapid and accurate response (a). Air is supplied o the cars at 110 psi through the supply line to the application relay and break-in-two protection relay. The straight air line controls the application relay on each car. The application relay regulates the maximum air pressure supplied to the release and application brake cylinders and the volume reservoir. This pressure is predetermined, depending on the retarding rate desired, and is nominally 60 psi. The release and application cylinders are of the same area and mounted to oppose each other in operating the brake linkage (b). The force of the release cylinder is applied through a slightly longer lever arm than that of the application cylinder so that, when the pressures in each are equal, the brakes are released.

Summary

The General Motors Aerotrain was designed to meet 3 important objectives: (a) reduce train weight by more than 50 per cent, (b) reduce train investment by almost 60 per cent, and (c) reduce train maintenance and operating expenses by nearly 60 per cent.

In meeting these major objectives, the Aerotrain presents several important "firsts" in railroading:

- Combination of a steel underframe with an aluminum body to reduce weight while maintaining safety
- Application of air-ride suspension to rail equipment using a 4- rather than 8-wheeled car
- Achievement of low center of gravity without sacrificing passenger height
- Design of a locomotive in complete harmony with the train to achieve maximum performance and economy
- Design of a passenger car with a body that can be replaced at a fraction of the cost of refurbishing a conventional car
- Design of car equipment specifically for the use of head-end electric power (in the locomotive) throughout the train.

After being exhibited at the General Motors "Powerama" in Chicago last September, 2 identical Aerotrains began initial demonstration runs on the Pennsylvania and New York Central railroads. The trains are now being tested on various railroads throughout the United States, and the program is scheduled for completion late this summer.

The Aerotrain is an experimental train on which developmental work still continues. The engineering questions it attempts to resolve are: how to make a passenger train light in weight while improving riding comfort and maintaining safety standards and how to substantially lower investment and operating costs while at the same time improving performance. The Aerotrain presents a working answer to these problems.

Fabrication of a Welded Steel Crankcase for a Large, 2-Cycle Diesel or Natural Gas Engine

By LEO L. YOUNG
Cleveland Diesel Engine Division

A unique design and welding technique to manufacture a 9-ft long, lightweight crankcase

The design specifications for the crankcase of a 2-cycle Diesel or natural gas engine, recently developed by the Cleveland Diesel Engine Division, called for its construction to be of a welded assembly of steel forgings and steel plates for the purpose of fulfilling specific weight and strength requirements. To meet design specifications, the manufacturing process engineer had to devise specialized welding fixtures and techniques which would allow effective use of the automatic submerged-arc welding process, in addition to assuring efficient and economic production.

A RECENT development by the Cleveland Diesel Engine Division is a radial, 2-cycle, 12.5-in. bore by 14.5-in. stroke engine designed to operate on either Diesel fuel oil or natural gas (Fig. 1). This engine, classified as GM Model 16-358, is used for stationary power generation and also for supplying motive power for various types of marine vessels. The engine can be operated in either a horizontal or vertical position depending upon installation requirements.

A vital component of the Model 16-358 engine is the crankcase. The design requirements for the engine specified that the crankcase be lightweight and also able to withstand extreme operating pressures and stresses.

A considerable amount of developmental time was devoted to designing the crankcase in order to satisfy design requirements and also to achieve a design which would allow economical production. It was first decided that the crankcase would be of cast construction. Further investigation indicated, however, that design specifications would be better fulfilled by constructing the crankcase of a welded assembly of steel forgings.

After the final crankcase design had been established, it became the responsibility of the manufacturing process engineer to devise specialized welding fixtures and techniques along with specially designed and modified machine tools to make possible the most efficient fabrication of a crankcase assembly.

The material and nature of the crankcase design required careful planning before a final method was perfected for the economical and efficient manufacture of the crankcase assembly which has the appearance of a well-designed casting but possesses the physical properties of steel (Fig. 2).

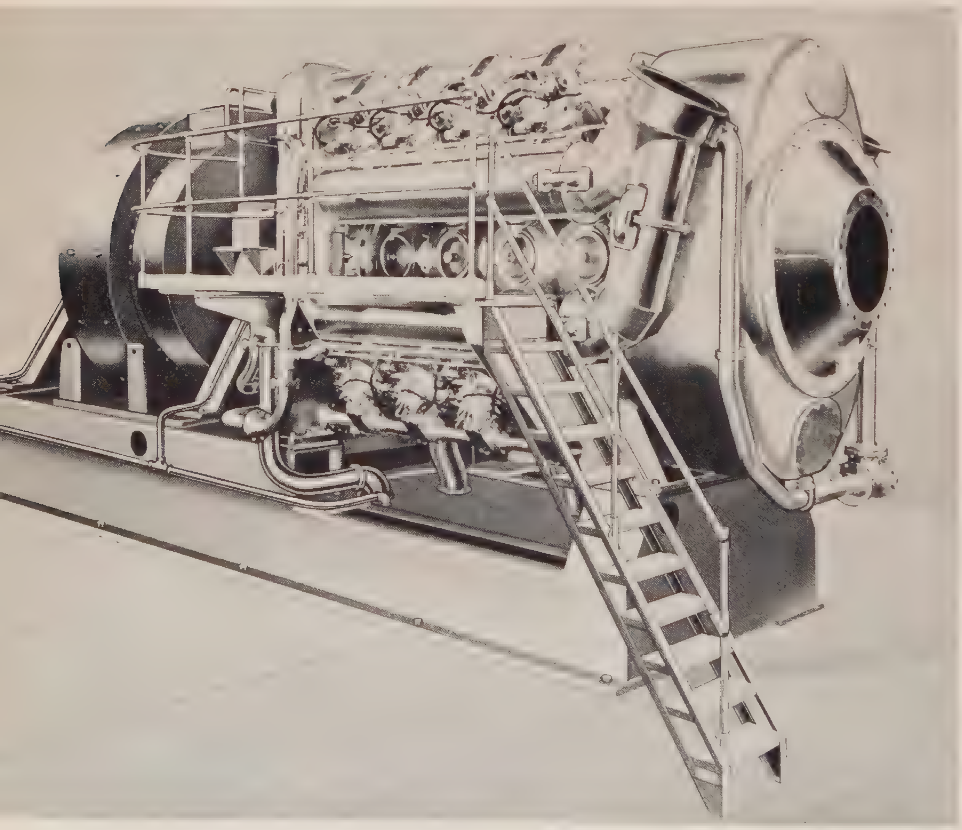


Fig. 1—The GM Model 16-358 radial, 16-cylinder, 2-cycle engine operates on either Diesel fuel oil or natural gas and can function in either a vertical or horizontal position depending upon installation requirements.

Crankcase Sub-Assembly Fabrication Procedure

The 16 cylinders of the Model 16-358 engine are arranged in the crankcase in 4 banks. Each bank has 4 cylinders radially spaced around a forged steel, 4-throw crankshaft. The crankcase assembly is begun by welding together cylinder attaching flanges to form a 4-cylinder ring segment sub-assembly (Fig. 3).

The loads imposed on the cylinder attaching flanges necessitate the use of a steel alloy forging having a carbon content low enough to permit easy welding, in addition to desirable heat

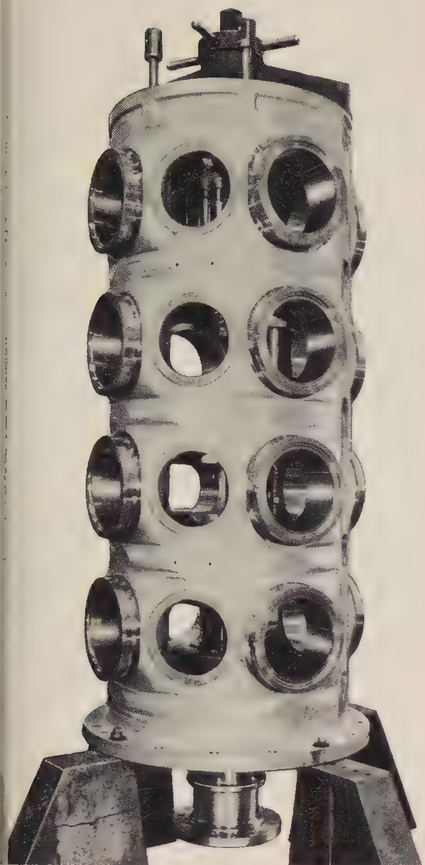


Fig. 2—The completely welded and machined 9-ft long crankcase for the Model 16-358 engine has 4 banks of 4 cylinders each which are radially spaced around a forged steel crankshaft. Main-bearing rings are placed between each bank of cylinders. Eight access holes, 4 on each side, provide a means for servicing the crankcase interior.

Fig. 3—The first step in fabricating the crankcase consists of welding together, by the submerged-arc welding process, 4 individual cylinder attaching flanges (shown inset) to form a 4-cylinder ring segment sub-assembly.

treating qualities to obtain the required strength and hardness. An 86B20 steel alloy which has the following chemical analysis is used for the forgings: manganese, 0.70 per cent to 1.00 per cent; phosphorous, 0.040 per cent; sulfur, 0.040 per cent; silicon, 0.20 per cent to 0.35 per cent; nickel, 0.40 per cent to 0.70 per cent; chromium, 0.40 per cent to 0.65 per cent; molybdenum, 0.15 per cent to 0.25 per cent; and boron, 0.0005 per cent to 0.003 per cent.

The cylinder attaching flanges, together with a clamping ring, provide the means by which each cylinder head and liner assembly is secured to the crankcase (Fig. 4). The inner, or back, face of the circular, cylinder attaching flange is machined and taper finished to correspond to similar machining on the outer surface of the cylinder. When the split, 2-piece cylinder clamping ring is assembled, the tapered surfaces of the cylinder and attaching flanges match with the taper of the clamping ring. It is highly important that all mating surfaces be accurately machined as no studs or bolts are used to hold the cylinder on the crankcase, and the clamping ring alone must withstand the internal gas pressures created by combustion.

The submerged-arc welding process is used for welding the crankcase sub-assemblies and final assembly. The interior welds joining together 4 individual cylinder attaching flanges to form 1 ring segment sub-assembly are made with the attaching flanges secured to the faceplate of a specially designed positioner (Fig. 5). This positioner, in turn, is an integral part of a special welding fixture developed to facilitate the use of the submerged-arc welding process for both the interior and exterior welds made on the 4-cylinder ring segment sub-assembly (Fig. 6).

Six interior welding passes, made at 35 v, 500 amp, and a welding speed of 10 in. per min, are used to join the attaching flanges. Waster plates are tack welded to each end of the weld line to assure proper arc penetration at the beginning and completion of the weld.

Experience has shown that the best interior welding results are obtained by pre-heating the sub-assembly prior to welding. Natural gas burners are directed on the sub-assembly until a temperature of 450° F is reached. The interior welds are then made.

Before the exterior welds can be made on the 4-cylinder ring segment sub-assembly, the unfused parent metal remaining at the bottom of the interior weld must be removed. Removal is

Fig. 4—The cylinder attaching flanges provic the means by which each cylinder and cylinde head (a) and cylinder liner (b) are secured to th crankcase by a split, 2-piece clamping ring (c The inner surface of the attaching flange is tapere to correspond with a similar taper on the out surface of the cylinder. These tapered surface in turn, match with a tapered surface on th clamping ring.

accomplished by the use of an arc-air "gun" which employs an electric arc to reduce the metal to a molten state and a jet of compressed air to blow the molten metal and slag out of the crater. The operator first strikes an arc to form a puddle of molten metal and then intermittently opens and closes an air valve to blow out newly formed puddles of molten metal. After the groove has been completely cleaned, the interior weld is then checked using the magnetic particle inspection method.

The exterior welds of the 4-cylinder ring segment sub-assembly are made in 8 passes each at 33 v, 500 amp, and a welding speed of 9 in. per min. During this welding operation, flux is manually deposited in advance of the welding arc's travel. Unused flux is recovered by a vacuum unit mounted near the welding fixture. After all exterior welds have been completed, the waster plates are removed and the sub-assembly's circumferential weld-joint faces are machined in preparation for final assembly of the crankcase.

The development of proper welding techniques for joining together the 2¼-in. thick cylinder attaching flanges into a 4-cylinder ring segment sub-assembly required a great deal of experimentation. Attempts were made to accomplish the welds with a reduced number of passes. The increased deposition of weld metal, however, resulted in elevated temperatures and a consequent increase in cracks and stresses within the weld.

Crankcase Final Assembly Procedure

The crankcase final assembly consists of 4 banks of cylinder ring segment sub-assemblies, 5 main-bearing rings, and a supporting flange all of which are welded together (Fig. 7).

The individual sub-assemblies are assembled into a completed crankcase assembly with the aid of 2 surveyor's transits located 90° to each other with respect to the crankcase final assembly fixture. The transits assure proper alignment of the sub-assemblies relative to each other and prevent "leaning" of the crankcase. After final alignment is completed, the individual sub-assemblies are tack welded together.

The welding procedure for the crank-

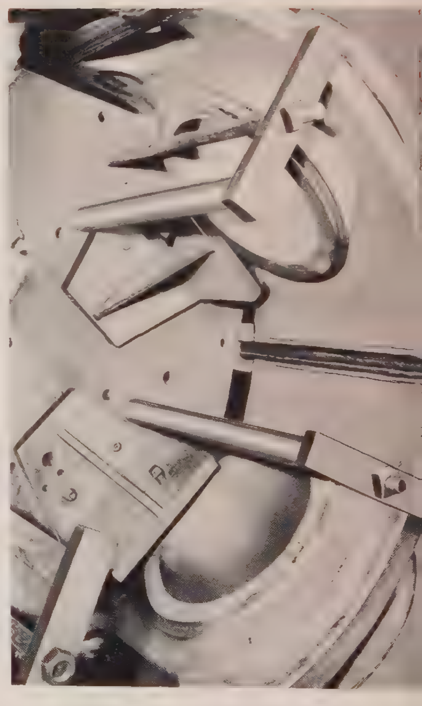


Fig. 5—The cylinder attaching flanges are secure to the faceplate of a specially designed weldir positioner while 6 interior passes are made o each weld joint. Waster plates are tack welde to each end of the interior weld line to assu proper arc penetration at the beginning and con pletion of the weld.

Fig. 6—Both the interior and exterior submerged-arc welds on the 4-cylinder ring segment sub-assembly are performed on the same welding fixture. The flux necessary for welding is manually deposited in advance of the welding arc's travel. Unused flux is recovered by a vacuum unit. A bent, copper nozzle *A* assures that the welding wire, which is fed from the drum shown at the upper right, will enter the weld joint at the proper angle. The operator is shown indexing the sub-assembly in preparation for the next exterior weld.

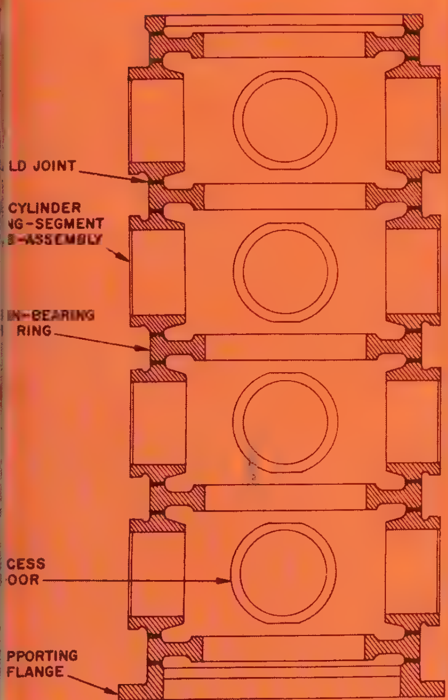


Fig. 7—A cross-section of the crankcase assembly shows the location of the 10 circumferential weld joints used to facilitate welding of the 4 ring segment sub-assemblies, 5 main bearing rings, and the supporting flange.

case final assembly calls for interior welds to be made first followed by exterior welds. A total of 10 weld joints are provided between the cylinder ring segments and the main-bearing rings.

Before the interior welds are made, trunnions (Fig. 8) are assembled to the crankcase assembly to support it in the welding fixture. The welding fixture (Fig. 9) was constructed of standard components. A horizontal arm supports the welding head and is extended or retracted to locate at each interior and exterior weld joint. Located in the bed of the welding fixture are 4 rolls which support and rotate the crankcase during welding. The crankcase is rotated over a horizontal pipe containing 15 natural gas burners which maintain the crankcase at the welding pre-heat temperature of 450° F. Initial pre-heat of the weldment is accomplished in a pit-type furnace.

When making the interior welds, the welding fixture's horizontal arm is extended inside the crankcase bore to the proper weld location. Only 1 pass is made on each interior weld, and this is done with a 3/16-in. diameter, low-manganese welding electrode at 32 v, 725 amp, and a welding speed of 10 in. per min.

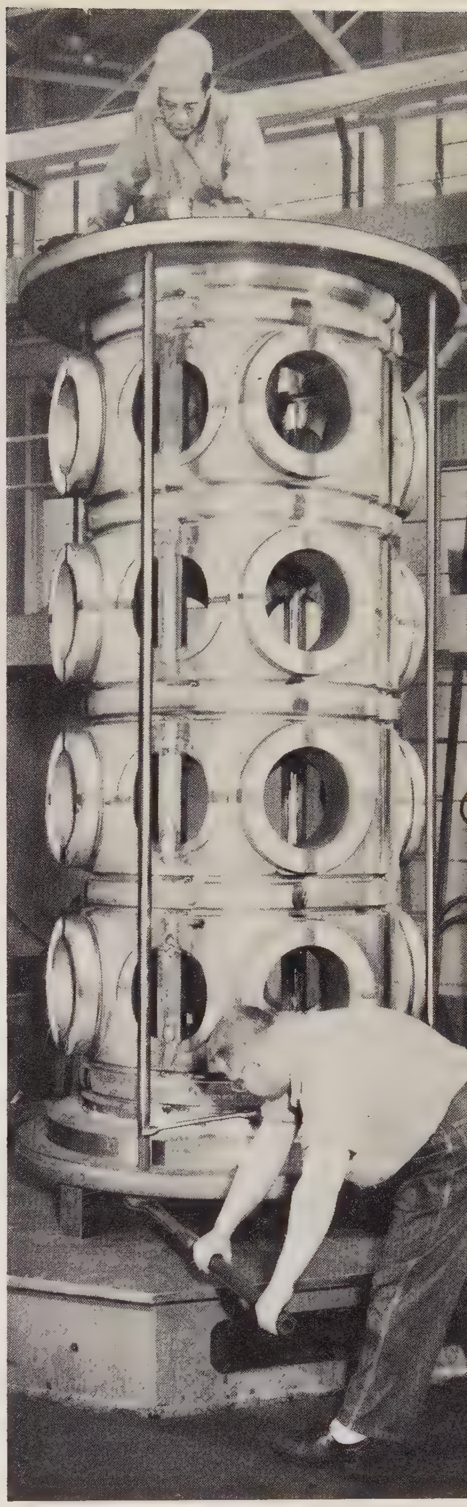
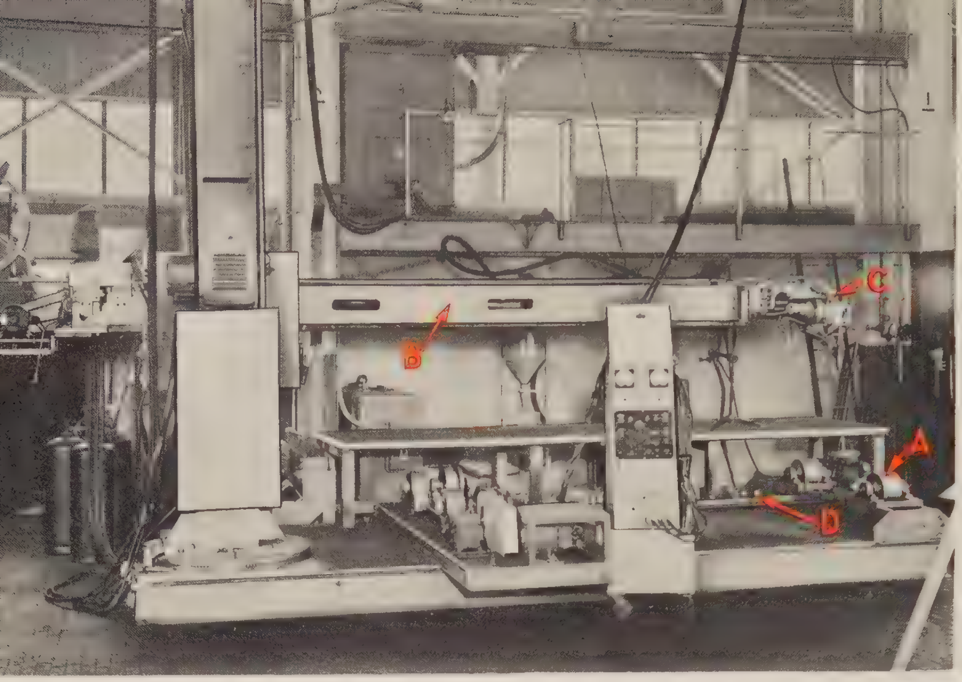


Fig. 8—Trunnions are assembled to the crankcase assembly to support it in the welding fixture while interior welds are made.

When the interior welds are completed, the crankcase is removed from the welding fixture and placed in a vertical boring mill. The interior welds are then back-grooved to remove unfused metal and to prepare the crankcase for the



These holes remove a section of both circumferential and longitudinal welds which are squared off, polished, and then etched to provide another check for weld quality.

The crankcase is then stress-relieved at a temperature of 1,050° F and sand-blasted to prepare it for machining. The quality of welding is further insured by an X-ray inspection of the entire crankcase under a sampling plan. After the X-ray inspection is completed, the crankcase is then ready for a series of machining operations.

Machining Operations

The first machining operations performed consist of boring and facing the crankcase bore. These 2 operations are performed by a vertical boring mill (Fig.

Fig. 9—Both the interior and exterior welds on the completed crankcase assembly are performed on the same welding fixture which was specially designed to facilitate use of the submerged-arc welding process. The crankcase is supported and rotated on 4 rollers *A* during the welding operation. A horizontal arm *B* supports the welding head *C* and is extended or retracted to locate each interior and exterior weld joint. A horizontal pipe *D* contains natural gas burners to maintain the crankcase at 450° F welding pre-heat temperature.

exterior welds. The crankcase is then returned to the pit-type furnace to be pre-heated to 450° F prior to exterior welding.

A total of 14 exterior-weld passes are placed in each of the 10 weld joints on the crankcase assembly. The first pass is made at 32 v, 500 amp, and a welding speed of 14 in. per min. Succeeding passes are made at increased rates of voltage and amperage and decreased welding speeds. The fourteenth pass is made at 35 v, 725 amp, and a welding speed of 10 in. per min.

During the course of placing the exterior welds a number of magnetic particle inspections are made, and any needed repairs are immediately performed. A final inspection by this method of both the circumferential and longitudinal welds also is made at the completion of the exterior welding.

A series of 4 access holes are then flame-cut out of 2 sides of the crankcase.

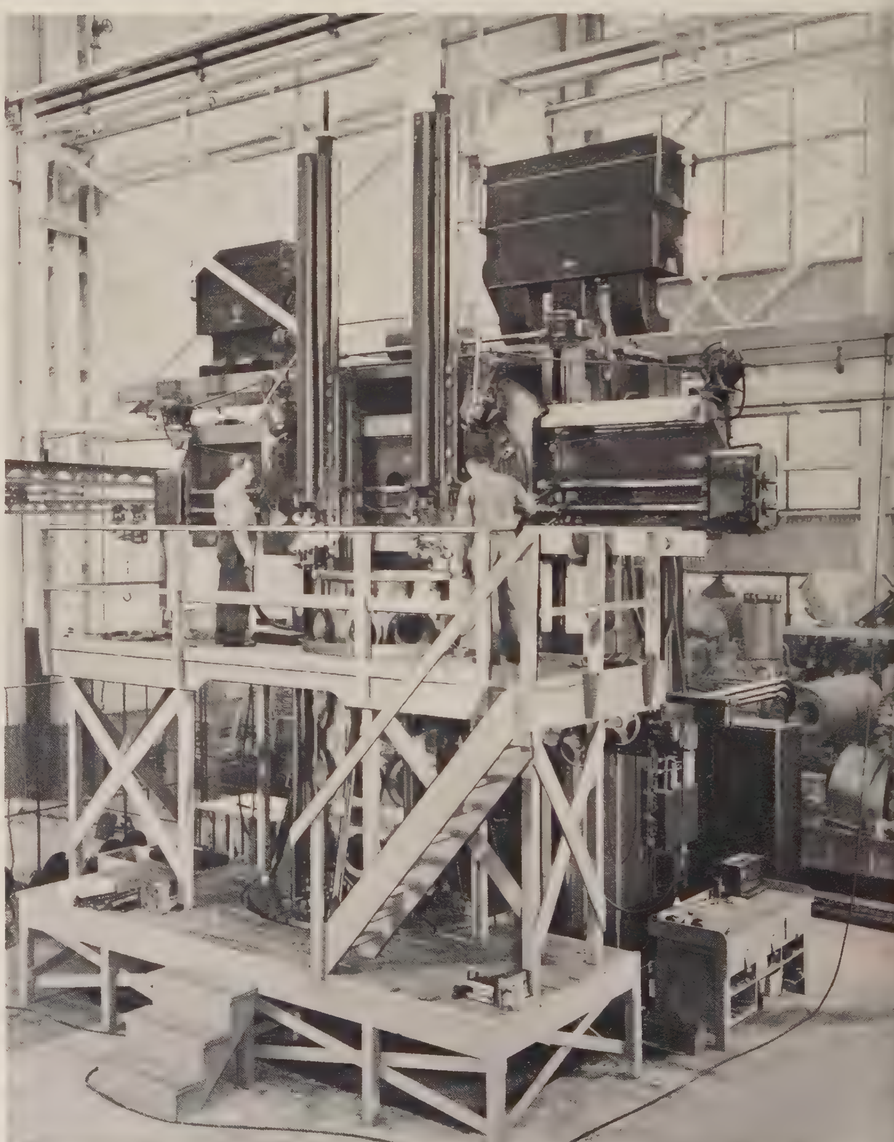


Fig. 10—A specially constructed vertical boring mill provides extra height for the accommodation of the 9-ft long crankcase while it is being bored and faced.

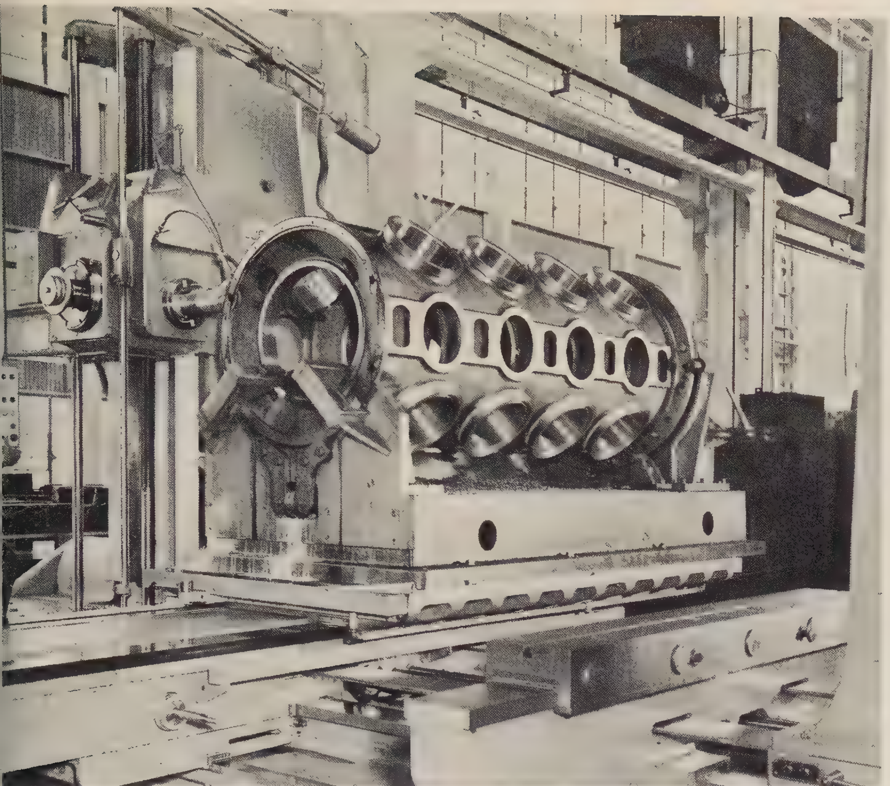


Fig. 11—The exterior plane surfaces on the crankcase are milled on a horizontal boring mill.

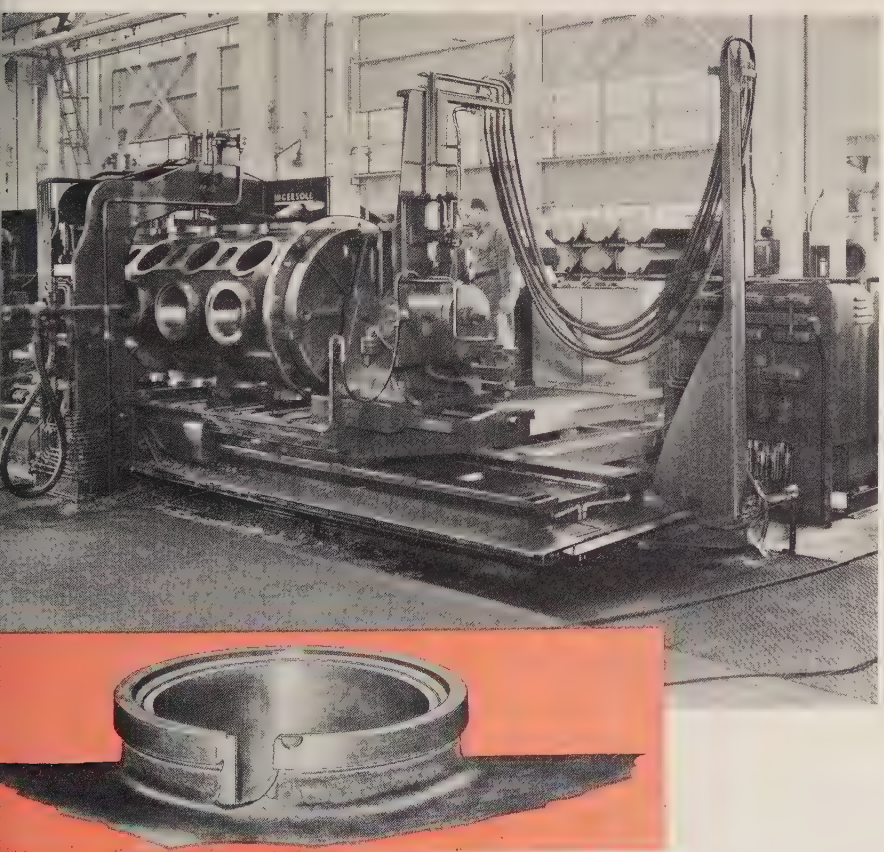


Fig. 12—The turning, boring, counter-boring, under-cutting, and taper-facing required on the inner and outer surface of each cylinder attaching flange (inset) are performed in 1 operation on a machine specially designed for this purpose.

10) which was specially constructed to provide extra height to accommodate the 9-ft. long crankcase.

The supporting flange is drilled next. The holes drilled in this operation provide the index for the remainder of the machining operations.

The exterior plane surfaces of the crankcase are then milled on a horizontal boring mill (Fig. 11). An identical fixture is used to support the part during the various drilling operations.

The cylinder flange (Fig. 12 inset) to which the split, 2-piece clamping ring is attached requires turning, boring, counter-boring, under-cutting, and taper facing of the surface adjacent to the crankcase. These operations presented a problem when outlining the machining operations to be performed. Such operations, if performed separately and by standard machine tools, would be tedious and expensive. A solution to the problem of performing the machining operations on this particular part was solved with the development of a special machine which performs all operations in 1 pass (Fig. 12).

At each main-bearing bore, a radial 1¼-in. diameter dowel hole is required. The surface in which the hole is drilled was not accessible by standard machine tools. This necessitated the development of a special offset spindle extension to be used on a radial drill press.

The remainder of the machining operations performed on the crankcase assembly are, in general, relatively standard in nature and do not require the use of specialized machine tools.

Summary

The design and material of the Model 16-358 engine's crankcase required a great amount of developmental time before a final procedure was established for its manufacture. Many engineering decisions had to be made and experimental runs performed before the specialized techniques described here were successfully applied to fabricating the welded steel crankcase by the use of the automatic submerged-arc welding process.

The production requirements for the Model 16-358 engine are not sufficient to justify special machine tools for all machining operations. The flexibility of standard machine tools, however, made possible the special modifications required for some of the more intricate operations performed.

Bench Test Simplifies Search for Better Cam and Tappet Materials

By GEORGE H. ROBINSON
General Motors
Research Staff

Reduce the problem to simple terms, and often the solution is obvious

Trends toward higher compression engines have dictated a need for better tappet and camshaft materials, as well as improved engine lubricating oils. The use of higher lift cams and stronger valve springs has increased the stresses at cam and tappet contact surfaces, in many cases causing spalling, wear, and scuffing of the tappet foot. Scuffing is a particularly serious type of failure since it almost invariably results in severe wear of the mating cam. Moreover, lubricating oil affects tappet performance; some tappet-cam combinations will perform satisfactorily with one oil and fail with another. After considering a number of approaches to the problem of evaluating cam and tappet materials, metallurgists of the General Motors Research Staff devised a bench-type test which permitted precise control over such variables as load, speed, and severity of operating conditions. Test results provided quantitative ratings of tappet and cam materials and engine lubricants.

A TEST program designed to develop better cam and tappet materials can be conducted in several ways. One way is to examine field service failures. This method has the obvious disadvantage that the manufacturer must be in serious trouble before the test program can begin. A better method is to conduct the evaluation with a fleet of test cars, although differences in driving conditions and variations between individual engines would result in considerable scatter of the data. A more satisfactory method would be to test the materials in an engine coupled to a dynamometer where load and speed can be regulated and severity of operating conditions can be increased to accelerate failure of borderline materials. Even under such closely controlled conditions, however, scatter is excessive (Fig. 1). In view of the complexities involved, it appeared to Research Staff engineers that the most satisfactory solution would be a bench test which would simulate cam and tappet operation close enough to permit a reasonable interpretation of the test results in terms of service performance, and yet be sufficiently reproducible to yield useful information from a small number of tests.

Bench Test Machine

In developing a bench test machine (Fig. 2) the necessary close relationship between the test conditions and actual tappet operation was achieved by using conventional design tappets and cams as the test samples. The cam samples were sections of production crankshafts, th

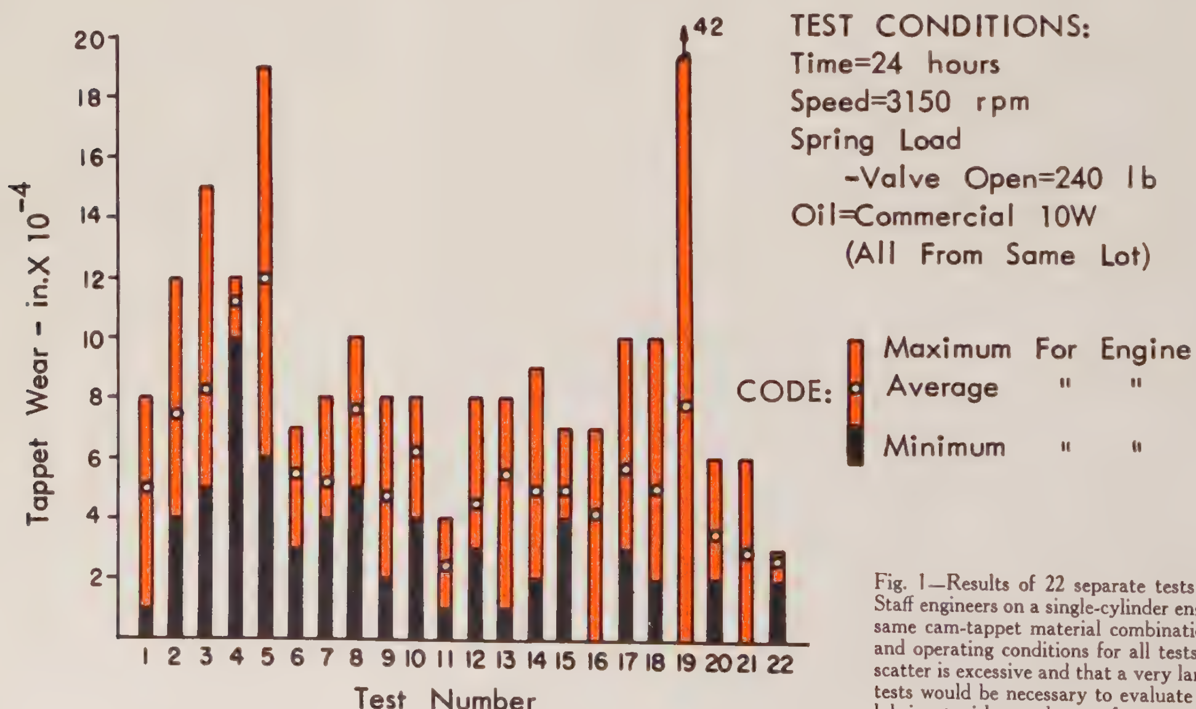


Fig. 1—Results of 22 separate tests by Research Staff engineers on a single-cylinder engine using the same cam-tappet material combination, lubricant, and operating conditions for all tests showed that scatter is excessive and that a very large number of tests would be necessary to evaluate a material or lubricant with any degree of accuracy.

ournals of which were machined to fit he bearings of the test machine.

Since contact load is a major factor in appet operation, the machine was de-igned to permit accurate measurement nd control of loads (Fig. 3). When the am lifts the tappet against the load pring, a tensile stress proportional to he cam-tappet contact load is produced n the load stem and is reflected by a hange in resistance of bonded-wire train gages attached to the thinly walled ortion of the stem. The load may be aried by turning the threaded cap, vhich compresses the load spring as it is crewed down. The system is calibrated y applying known loads with a tensile est machine or spring tester and noting he corresponding strain gage readings. Although loads are ordinarily measured tatically with the cam at position of naximum lift, dynamic loads during peration may also be measured by neans of suitable recording equipment.

Test Procedures

Due to the variety of problems for vhich the machine has been employed, no one standardized test procedure has een formulated. Rather, the procedure s varied to suit the individual problem.

For evaluating wear resistance of ma-erials and anti-wear properties of lubri-cating oils, a single cam-tappet set is perated at progressively increased loads, nd tappet wear is determined after each un by measuring the change in length of the tappet with a dial indicator gauge. This procedure reveals the sensitivity to contact load of the material and lubri-cant combination being studied. After a high load (400 lb to 500 lb) has been attained in this manner, the tappet may be operated at constant load to determine wear rate (Fig. 4).

Another general procedure is employed for studying scuffing tendencies of ma-erials. For this type of evaluation a cam-appet set is run at some load for a short ime. If no scuffing occurs, a new set is ested at a higher load. This process is epeated until scuffing failure occurs. The load at which scuffing is first en-countered is, thus, a measure of the scuffing tendency of the material com-bination being evaluated.

Material Evaluation

A series of tests was run at the request of a General Motors Division on the basis of reports that tappets from vendor "B"

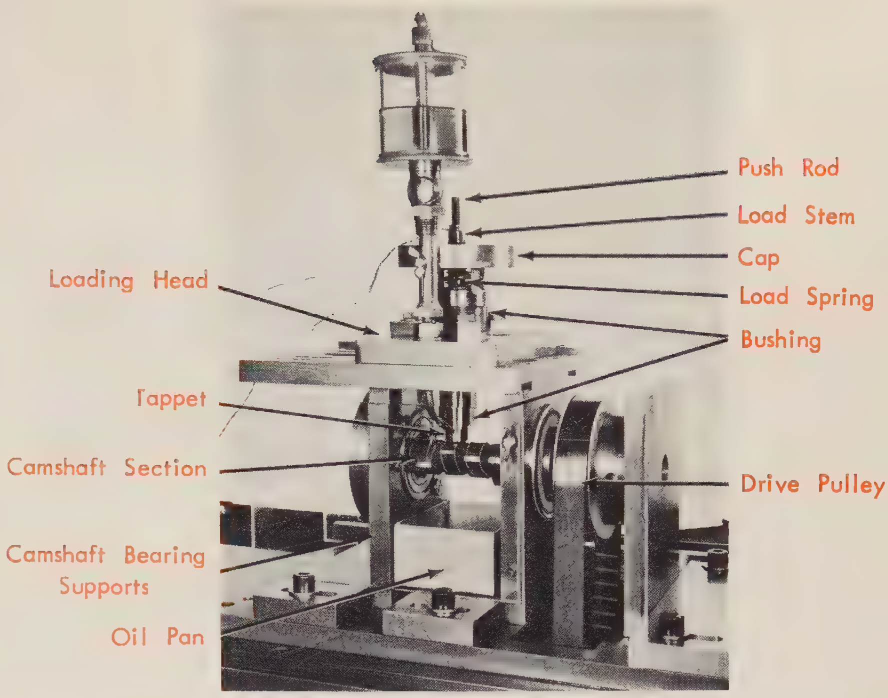


Fig. 2—This overall view of the tappet test machine shows the arrangement of components and the simplicity of construction. The load on the tappet is accurately controlled and can be varied over a wide range. Lubricant is metered to the cam-tappet contact area from the oil cup.

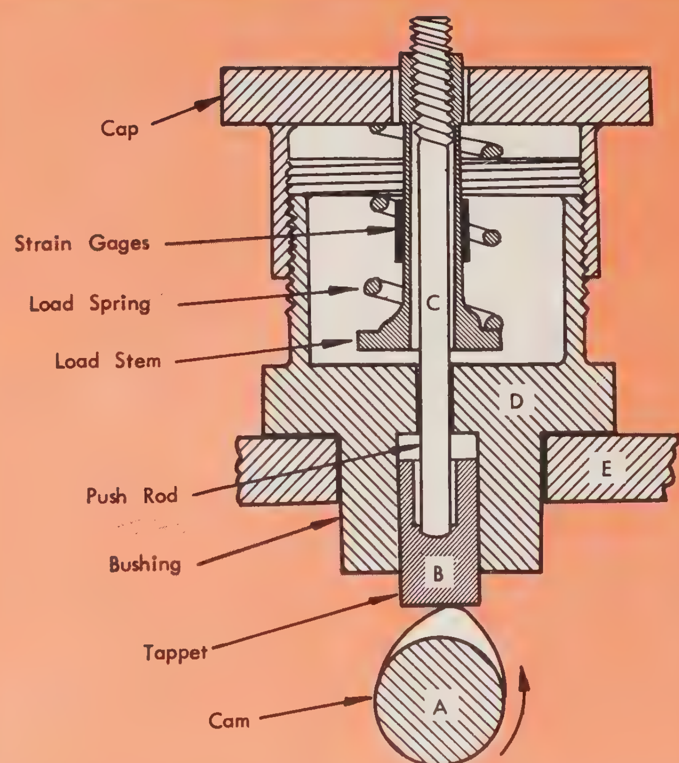


Fig. 3—This schematic diagram of the bench test machine shows the method of loading. The camshaft section *A* is driven by a ½-hp electric motor through a timing belt and toothed pulley system, and the tappet *B* is held against the rotating cam by a spring-loaded push rod *C*. The tappet rides in a bushing *D* attached to a loading head *E*, which is moved to position the tappet over the cam. Any type of tappet may be used by making the bushing to fit the tappet body, and the machine will accommodate either line-6 or V-8 design camshaft sections.

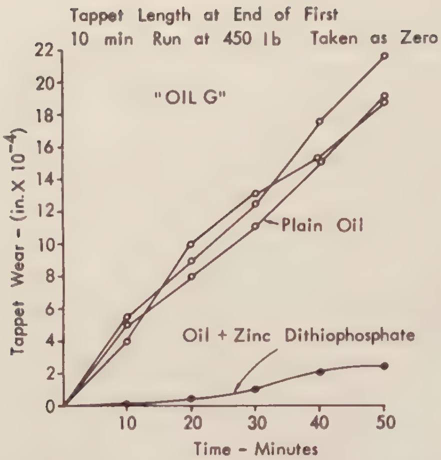


Fig. 4—The upper curves represent 3 tests of steel tappets run with the same lubricating oil. The agreement of the 3 curves indicates the degree of reproducibility of results obtainable with the test machine. The lower curve was obtained when 1 per cent of zinc dioctyldiophosphate was added to the oil and shows the pronounced effect of this particular oil additive on the wear behavior of steel tappets. The beneficial effect of this additive also has been established by a considerable number of field and dynamometer tests.

appeared to perform better than tappets from vendor "A." The test machine results provided a quantitative evaluation which showed that tappets from vendor "B" were significantly more resistant to scuffing than the tappets from vendor "A" (Fig. 5). Scuffing was encountered with the "A" tappets at 125 lb to 150 lb,

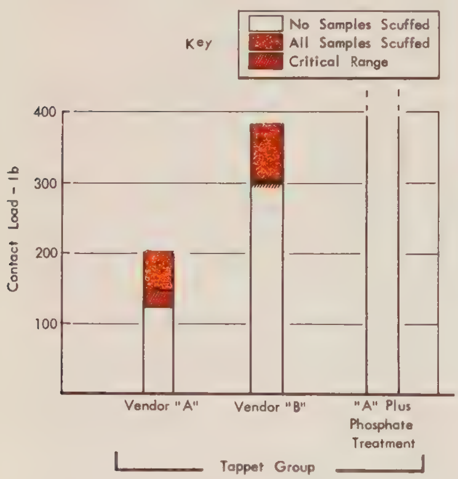


Fig. 5—A series of tests was run on the basis of reports that tappets from vendor "B" performed better than those from vendor "A." Scuffing was encountered with the tappets from vendor "A" at 125 lb to 150 lb, while the tappets from vendor "B" operated without scuffing at loads up to 300 lb. Further tests showed, however, that application of a phosphate surface treatment to the tappets from vendor "A" produced an even greater improvement in scuff resistance, since no scuffing was encountered with surface-treated tappets at 400 lb contact load.

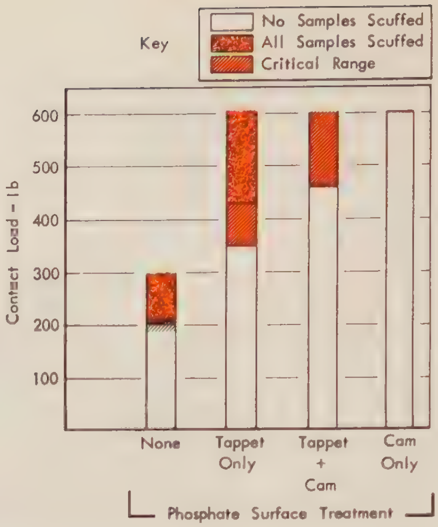


Fig. 6—Treating the tappet with a phosphate coating increased the minimum scuffing load from 200 lb to 350 lb, which is in agreement with previous experience. The greatest resistance to scuffing, however, was observed when only the cam was treated, and treating both components gave intermediate results. (Test conditions for this evaluation differed from those of the previous tests, and the data of Figs. 5 and 6, therefore, cannot be compared directly.)

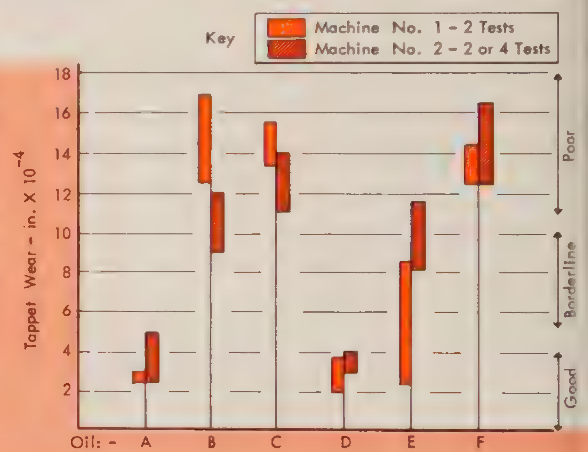


Fig. 7—Two identical bench test machines gave the same relative ratings to 6 commercial lubricating oils. Field test evaluations of oils A and B were in complete agreement with results obtained from the bench test machines. Field test evaluations of oils C, D, E, and F were not complete at the time of this writing, but preliminary results have confirmed the test machine ratings.

while the "B" tappets operated without scuffing at loads up to 300 lb. Further tests showed, however, that application of a phosphate surface treatment to the tappets from vendor "A" produced an even greater improvement in scuff resistance, since no scuffing was encountered with surface-treated tappets at 400-lb contact load.

The beneficial effect of the phosphate surface treatment is generally recognized, and such treatments are commonly employed for tappets and cams. However, some manufacturers treat only the tappet, and others treat only the cam, while still others treat both parts. Some additional tests were made to determine the most effective means of employing the phosphate coating (Fig. 6).

Lubricating Oil Evaluation

In addition to its usefulness in material evaluation, the bench test machine has shown considerable promise as a means of rating lubricating oils.

Two commercial motor oils which had been rated previously by means of car and dynamometer tests were checked in the bench test machine. The machine rated the oils correctly with regard to their service performance. The "good" oil was found to produce only ¼ to ⅛ the tappet wear observed with the "poor" oil.

In view of these results, a second tappet test machine was built specifically for use in oil evaluation studies. Results of independent tests by the 2 machines of 6 commercial lubricating oils showed that both machines rated the oils in the same general way and that the tappet wear levels observed with corresponding oils on the 2 machines also agreed quite closely for the most part (Fig. 7).

Summary

The time element and number of uncontrollable variables encountered in attempting to rate tappet and camshaft materials and lubricating oils by means of field and dynamometer tests emphasized the need for a reliable bench test which would correlate with service performance in the field and at the same time permit rapid and reproducible testing of tappets and camshafts under a wide variety of operating conditions. Such a machine was designed and built by Research Staff engineers and has performed well in material and lubricant evaluation problems.

Notes About Inventions and Inventors

By JOHN W. LOVETT
Patent Section
Central Office Staff

The chances are good that engineers will also be inventors

POSSIBLY many a young engineer or engineering student, after reading prior articles in the GENERAL MOTORS ENGINEERING JOURNAL about "Inventions and Inventors" has asked himself the question, "What are the chances that I will ever make an invention?"

The answer to this question depends to a great extent on just what he considers to be an "invention." Perhaps he is thinking about something of a revolutionary nature which will cause the whole world to acclaim him as a great inventor and result in fame and fortune. If so, he might be inclined to believe the opinions that have been expressed by others, including even a Commissioner of Patents not too many years ago, that everything has been invented.

With reference to such a belief, one has only to look at the progress this country has made to realize that a debt of gratitude is owed to those who refused to accept the fallacy that nothing is new under the sun. Progress is based on continuing developments. As long as the aim of industry is to develop and produce "more and better things for more people" the opportunities for engineers to benefit both themselves and others will be constantly expanding in this land of ours. This is not only the cause but also the effect of progress.

The writings of Jules Verne were considered to be fantastic during his lifetime. Yet in a little more than 50 years there has been a transition from hand labor to machine labor, from horse-drawn vehicles to automobiles and airplanes, from hand-fired coal burners to automatic stokers, oil and gas burners, and, more recently, nuclear energy, which has so many future possibilities as to be beyond the comprehension of the most imaginative minds of only a few years ago.

Advances in Science and Technology

Just what has been the effect of constant advances in science and technology on the opportunities for invention? The answer to this question should be obvious when one considers that the many products which are considered to be so essential to the nation's well-being and high standards of living were not developed overnight but have resulted from years and years of constant evolution. These products depend upon pure science, which created scientific knowledge, but it is always the practical application of this knowledge which is responsible for the actual developments and the creation and growth of industries. Years of pure scientific research on energy waves, for instance, preceded the practical application of that knowledge to radio, which has advanced from the cat's whisker and crystal to high-fidelity sound reproduction.

Before the twentieth century, industry relied upon the independent inventor to a considerable extent to develop something which would be marketable and justify the investment necessary for commercialization on a production basis. But if industries were to prosper and expand, it was only logical that new and better products would have to be developed. Thus, practically every industry has undertaken its own program of scientific research and the practical application of scientific knowledge by engineers to develop new and improved products.

Each advance in science and technology opens up a bigger field for further developments and inventions. Usually this involves the solving of many technical and scientific problems in the constant search for improvements in existing products, as well as the design and development of new products. While there will always be the occasional "basic" invention, the efforts of industry are largely directed toward improvements on prior inventions. As with basic inventions, the field here is practically limitless, also. In industry, engineering and research activities are essential insurance to continued success. Research is never satisfied as long as improvement remains possible. There has never been a saturation point for improvements, and there never will be.

Inventor or Engineer

Only an independent or professional inventor whose living depends on developing something patentable should devote his time and energy to the task of deliberately trying to conceive patentable inventions. An engineer in industry who is concerned with curing an existing defect or designing a new or improved product should concentrate on these problems without regard as to whether anything he may develop qualifies technically as an invention from the standpoint of the patent law. It is only after he believes he has a practical solution to the particular problem that the engineer should be interested in determining if his development includes any ideas that constitute patentable inventions. The chances, however, that an engineer will invent are very good.

Importance of Patent System

The importance of the patent system in promoting advances in science and technology, which are the bases of all progress, should not be overlooked. There are those who would seek to weaken or even destroy the patent system by misrepresenting the nature of the patent monopoly and the part which patents play in encouraging inventions and their prompt disclosure to the public. Representations that patents tend to stifle rather than promote advances in science and industry in this country can only be based on distortion of facts by impractical theorists. If the possibility of patent protection did not exist, the inevitable alternative of secrecy would retard the

progress of both science and industry in this country. Even though it might be argued that attempts at secrecy usually might fail within a few years, it is inescapable that there would be such a slowing down of the exchange of basic information and new ideas that industrial progress would proceed only at a snail's pace. The patent system was designed and functions to promote progress by protecting the rights of those who disclose their inventions.

Patents Granted

On this and on the following pages are listed some of the patents granted to General Motors prior to January 31, 1956. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

• **Arthur V. Lander, Louis W. Gomm, and Nelson J. Smith,** *Frigidaire Division, Dayton, Ohio, for a Refrigerator Cabinet Breaker Strip, No. 2,708,529, issued May 17.* This patent relates to the construction of an insulated breaker strip between inner and outer refrigerator cabinet metal walls which strip can be tightly locked to the walls against removal therefrom.

Mr. Lander is assistant chief engineer in the Engineering Department of Frigidaire Division of GM Limited, London, England, having begun his career with this Division in 1933. He attended Clifton College in Bristol, England. Most of his design work has been related to refrigeration cabinets and systems. Mr. Lander is an associate member of the Institute of Refrigeration and a council member of the Frigidaire Engineering Society.

Mr. Smith has been chief engineer of Frigidaire Division, GM France, since 1951. His GM career began with Frigidaire in Dayton, Ohio, as an apprentice engineer in 1928. In 1946 he was assigned to the Overseas Operations Division as process engineer and in 1948 became chief engineer of Frigidaire Division, GM Limited in England. The University of Cincinnati granted him the B.S.M.E. in 1928.

Mr. Gomm is no longer with the Division.

• **Melvin F. Penn,** *Frigidaire Division, Dayton, Ohio, for a Lubricant Return in Refrigerating Apparatus, No. 2,719,408, issued October 5.* This is a sealed motor-compressor unit in a refrigerating system wherein the invention resides in preventing refrigerant in the crankcase portion of the unit from flashing into vapor and discharging lubricating oil out of the crankcase when the unit starts operating.

Mr. Penn is senior project engineer in the Commercial Engineering Department of Frigidaire. He received the B.S.M.E. degree in 1929 from Virginia Polytechnic Institute. He has been with Frigidaire since 1930, starting as a tester and advancing to his present post in 1947. He is currently engaged in work on commercial air-cooled and water-cooled condensers and refrigerating units. Mr. Penn's work has resulted in several granted patents.

• **Hillard J. Jendrzynski,** *GM Research Staff, Detroit, Michigan, and* **Thomas F. Stapleton,** *Allison Division, Indianapolis, Indiana, for Nickel Plating by Chemical Reduction, No. 2,721,814, issued October 25.* This is an improved method of electroless nickel plating wherein the articles to be plated are immersed in a bath having specified concentrations of nickel ion and hypophosphite ion, as well as a specified temperature and pH, until subsequently all of the nickel ion in the solution has been reduced to form the desired plating.

Mr. Jendrzynski has been a research engineer in the Electro-Chemistry Department of the Research Staff since his employment in 1952. His current work is devoted to chemical reduction plating. He received the B.S. degree in 1947 from the Illinois Institute of Technology and studied at Harvard University from 1947 to 1948. In January 1956 he received the M.B.A. from the University of Detroit.

Mr. Stapleton joined GM in June 1953 as a junior engineer in the Electro-Chemistry Department of the Research Staff. Recently he transferred to Allison as an experimental engineer. He received the Bachelor of Chemical Engineering degree from the University of Detroit in 1953. His previous work with the Research Staff centered around the "Ni-chem" nickel plating process and a special plating machine for display in the GM Motorama.

***Inventors' names marked with an asterisk in this section have had their biographies published in a previous issue of Volume 3, General Motors Engineering Journal**

• **Rudolph C. Weide,** *Electro-Motive Division, LaGrange, Illinois, for a Resistance Grid, No. 2,721,920, issued October 25.* This covers a support for a serpentine resistor grid whereby the bends of the grid are cradled remotely from the supporting insulators by unique cup-like extensions.

Mr. Weide has been project engineer at Electro-Motive since joining the Division in 1949. His design work is in the field of electro-mechanical equipment such as for Diesel-electric oil well drilling equipment and controls—his current project. Mr. Weide was educated in Germany receiving both mechanical engineering (1922) and electrical engineering (1937) degrees. Thirty-four patents have been granted as a result of his work.

• **Joseph D. Turlay*,** *Buick Motor Division, Flint, Michigan, for Engine Manufacturing Process, No. 2,722,049, issued November 1.* This invention relates to a process for manufacturing engines of different displacement from engine parts, most of which are identical.

• **Joseph D. Turlay*,** *Buick Motor Division, Flint, Michigan, for Inlet Manifold System, No. 2,725,047, issued November 29.* This invention relates to an inlet manifold for V-type engines having a novel arrangement of main distribution and branch passages and having a novel arrangement of chambers for heating the branch passages of the manifold.

• **Joseph D. Turlay*,** *Buick Motor Division, Flint, Michigan, for Intake Manifold, No. 2,725,859, issued December 6.* This invention relates to an intake manifold for a V-type engine employing 4 side draft carburetors and a linkage system for actuating the throttle valves in the various carburetors so that a portion of the carburetors will act as primary carburetors and will be operative at all times, and the remaining portion of the carburetors will act as secondary carburetors and will be operative only during heavy loads.

• **Anton F. Erickson,** *Moraine Products Division, Dayton, Ohio, for Outlet Valve for Master Cylinder, No. 2,722,103, issued November 1.* This invention relates to a double acting check valve for hydraulic brake master cylinders. The valve is made of 2 stampings which provide a cage to positively position and confine a rubber valve element to prevent com-

plete brake failure on deterioration of the rubber valve element.

Mr. Erickson is assistant supervisor of brake research engineering. He was employed in 1937 as a brake engineer by Delco Brake Division, which merged with Moraine Products in 1942. His subsequent promotions have been to general foreman, 1942, and assistant supervisor, 1944. He was promoted to his present position in 1954. Several patents have been granted as a result of his work.

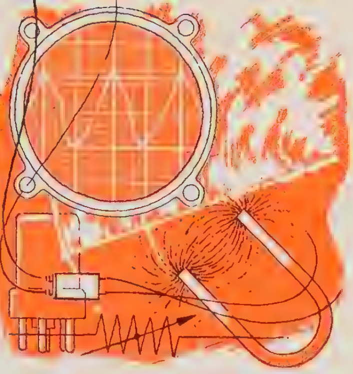
• **Argyle G. Lautzenhiser,** *Delco-Remy Division, Anderson, Indiana, for Hydraulic Governor, No. 2,722,205, issued November 1.* This patent relates to a pump-driven hydraulic speed governor which is combined with and driven with the engine lubricating oil pump.

Mr. Lautzenhiser is research engineer at Delco-Remy. He earned the B.S. degree in electrical engineering from Tri-State College, Angola, Indiana, in 1940. After his employment by Delco-Remy in 1940 as a laboratory technician, he was promoted to special tester in 1942 and to research engineer in 1948. He served in the Army from 1944 until 1946.

• **Charles H. Beare, Stanley R. Carson, and Russel L. Monbeck,** *Inland Manufacturing Division, Dayton, Ohio, for Method of Making Flexible Air Hose, No. 2,722,263, issued November 1.* This invention relates to a method for forming wire reinforced flexible air hoses as used in automobile ventilating systems. The method comprises extruding tape material with the reinforcing wire therein and then wrapping the tape upon a mandrel to form the hose.

Mr. Carson is supervisor of experimental engineering at Inland Manufacturing, where he was first employed in 1921 as a tool maker in the Tool Department. Later promotions to laboratory assignments led to his position as assistant superintendent and, eventually, to supervisor in the Experimental Engineering Department. Mr. Carson's work has resulted in several granted patents.

Mr. Monbeck is an experimental extruding die maker in the Experimental Engineering Department at Inland Manufacturing, where he was originally employed by the Tool Department in 1921. In 1940 he was transferred to the Control Laboratory and later to the Experimental Engineering Department,



where he was promoted to his present duties in 1950. Mr. Monbeck's work has resulted in the grant of 2 patents.

Mr. Beare is no longer with the Division.

• **Jesse E. Eshbaugh,** *AC Spark Plug Division, Flint, Michigan, for Filler Spout Closure, No. 2,722,338, issued November 1.* This patent relates to a closure for a gasoline tank filler spout in which neither the sealing gasket nor the spring thrust washer is riveted to the cap. These elements are loose in the cap, being centered by a detent arrangement.

• **Jesse E. Eshbaugh,** *AC Spark Plug Division, Flint, Michigan, for Magnetic Liquid Level Indicators, No. 2,728,227, issued December 27.* This invention pertains to an exterior indicator of liquid level in a container, the indication being given by magnetically attracted rolling bodies located on the opposite sides of the container wall.

Mr. Eshbaugh is staff engineer in the New Devices Department of AC Spark Plug, where he has been employed since 1926. His previous projects included work on pressure caps and relief valves. He received the M.E. degree from the University of Cincinnati in 1923. Mr. Eshbaugh is a member of the Tau Beta Pi honorary society and the S.A.E.

• **Ned F. Nickles,** *GM Styling Staff, Detroit, Michigan, for Combination Bumper Grille, No. 2,722,447, issued November 1.* This patent relates to the employment of vertically spaced, extending bumper guards carried by the main impact bar to additionally serve as the grille for the engine air intake opening at the front end of the car.

Mr. Nickles is chief designer in the Buick Studio of the Styling Staff. In 1940 he began work with Styling as a junior designer, and in 1943 he was promoted to senior designer. He became chief designer of Advanced Design in 1945 and assumed his present position in 1947. Mr. Nickles has had 2 patents granted as a result of his work. He is a member of the S.A.E.

• **Edward L. Barcus,** *Guide Lamp Division, Anderson, Indiana, for Direction Signal Switch, No. 2,722,577, issued November 1.* This patent relates to certain improvements in a manually set, automatically reset direction signal operating mechanism.

Mr. Barcus is a designer in Guide Lamp's Engineering Department, where he was first employed in 1935 as a tapping machine operator. Six patents have been granted as a result of his work on turn signals and automotive lighting equipment. Previously, Mr. Barcus was on special assignment on a confidential ordnance project and was a trouble analyzer for the M-3 sub-machine gun project.

• **Millard E. Fry*,** *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,722,591, issued November 1.* This patent discloses a simplified electric oven heater formed of longitudinal, thin steel channels supporting insulators. Coiled heater wire extends through the insulators. Transverse strips connect the channels and provide integral supporting feet.

• **Harry F. Clark,** *Frigidaire Division, Dayton, Ohio, for a Starting and Overload Control for Single-Phase Motors, No. 2,722,644, issued November 1.* In this patent a double-throw bimetallic switch is located in the food compartment of a refrigerator. This switch controls either of 2 heaters associated with oppositely acting bimetals of a thermal overload to operate the overload to start and stop the refrigerating system according to high and low temperatures in the food compartment.

Mr. Clark is senior project engineer in the Household Engineering Department of Frigidaire. After earning the electrical engineering degree from University of Cincinnati in 1921, Mr. Clark was employed by the GM Research Staff in Dayton as a research engineer in the Electrical Department. In 1925 Mr. Clark joined Frigidaire as a test engineer and became senior project engineer in 1947.

• **Leonard J. Mann,** *Frigidaire Division, Dayton, Ohio, for Refrigerating Apparatus, No. 2,723,533, issued November 15.* This invention relates to a household refrig-

erator wherein special means is provided for by-passing one of 2 evaporators which are normally connected in series refrigerant flow relationship.

• **Leonard J. Mann**, *Frigidaire Division, Dayton, Ohio, for Refrigerating Apparatus, No. 2,732,272, issued January 24.* This invention relates to an improved arrangement for attaching a molded breaker strip to the inner liner for a refrigerator cabinet.

Mr. Mann is a senior project engineer at Frigidaire, where he is engaged in development of household refrigerator units. He has served in his present capacity since 1953, and formerly his work was concerned with production engineering for refrigerator units. Mr. Mann's entire career has been with Frigidaire, starting in 1931. The University of Cincinnati awarded him the M.E. degree in 1940.

• **John H. Heidorn* and Thomas H. Fogt**, *Frigidaire Division, Dayton, Ohio, for Refrigerating Unit with Resilient Support, No. 2,723,538, issued November 15.* This patent relates to a mounting for anchoring a motor-compressor unit of a refrigerating system in a machine compartment of a refrigerator cabinet. Two substantially U-shaped, resilient mounting elements are equally spaced apart around the motor-compressor containing casing, and the legs of these elements cushion rotary movement of the casing, caused by starting and stopping of the motor, and converts same into a swinging movement of the casing in pendulum fashion.

Mr. Fogt is a project engineer in the Research Engineering Department of Frigidaire, where he began work in 1948 as a tester in the Household Engineering Department. He is currently working on rotary compressor development. He is a member of the Tau Beta Pi and Pi Mu Epsilon, honorary societies. This is the first patent granted as a result of his work.

• **Herman L. Hartzell**, *Delco-Remy Division, Anderson, Indiana, for Control Circuit, No. 2,723,654, issued November 15.* This invention relates to a circuit for controlling the resistance of the ignition circuit. This is accomplished by using a shunt circuit to cut out the resistance upon starting. The shunt circuit is established through a solenoid switch used for energizing the starting motor.

Mr. Hartzell is chief engineer at Delco-Remy. The Ohio State University granted him the B.E.E. degree in 1924. He joined GM in 1924 as a student engineer at Dayton Engineering Laboratories and transferred to Delco-Remy as a product engineer in 1927. Mr. Hartzell's research in the field of automotive electrical equipment has resulted in more than 40 granted patents.

• **Leland D. Cobb**, *New Departure Division, Bristol, Connecticut, for a Demountable Closure for Antifriction Bearings, No. 2,723,-869, issued November 15.* This patent relates to a closure, or seal, that may be demountably snapped into end-closing position in an antifriction bearing to retain lubricant within the bearing and to exclude dirt, water, and other deleterious materials.

Mr. Cobb serves as manager of the Research and Development Laboratory at New Departure. He started with the Division in 1928 as a junior engineer. Mr. Cobb's work in the fields of textile equipment, ball bearing seals, and special bearing designs has resulted in the grant of 19 patents. He is a member of the A.S.M.E. and S.A.E.

• **Clifford H. Wurtz***, *Frigidaire Division, Dayton, Ohio, for a Refrigerator Door Seal, No. 2,723,896, issued November 15.* This patent is for a magnetic arrangement of sealing flexible portions of gaskets on mating edges of 2 refrigerator cabinet doors at a mullionless joint between the doors. Permanent magnet segments enclosed in the rubber-like gaskets pull a sealing portion of the gasket on one door into engagement with a sealing portion of the gasket on the other door, when the doors are closed, to seal the joint therebetween.

• **Clifford H. Wurtz***, *Frigidaire Division, Dayton, Ohio, for Refrigerating Apparatus Including Defrosting Means, No. 2,731,806, issued January 24.* The freezing and food compartment evaporators shown in this patent are serially connected with the compressor and condenser. The compressor motor switch has 2 vapor-charged bulbs, one of which is connected in good heat contact with that portion of the refrigerant passage of the food compartment evaporator which is reached by the refrigerant when it is desired to stop the compressor, while the other bulb is insulated from this evaporator but located where the frost disappears last during the defrosting cycles.

• **Charles A. Nichols**, *Delco-Remy Division, Anderson, Indiana, for Method for Coating an Annular Article, No. 2,723,918, issued November 15.* This invention relates to an apparatus and method as used to insulate selected portions of a V-ring, which is used to maintain the commutator segments in position in the assembled commutator. The insulation is applied directly to the V-ring as a coating.

Mr. Nichols has been director of manufacturing facilities at Delco-Remy since 1953. A mechanical engineering graduate of Carnegie Institute of Technology, he joined Delco-Remy as a student engineer in 1923. He advanced through various positions, including superintendent of the foundry and master mechanic. His work has resulted in the grant of 18 patents in the field of special machinery.

• **Wayne H. Sheley, Max E. Todd and Richard M. Goodwin**, *Delco-Remy Division, Anderson, Indiana, for Machine for Removing Insulation, No. 2,724,136, issued November 22.* This invention relates to a machine for removing baked varnish insulation from the lead wires of electrical coils. The device is automatic in its operation and burns the insulation while protecting the coil and subsequently removes the charred insulation.

• **Richard M. Goodwin**, *Delco-Remy Division, Anderson, Indiana, for a Commutator Assembling Machine, No. 2,729,882, issued January 10.* This patent relates to a machine providing for automatic assembly of a predetermined number of metal bars and insulating separators arranged alternately in an annulus to form a commutator.

Mr. Sheley is an engineer in the Process Department at Delco-Remy, currently engaging in work on costs and methods analysis. Prior to this assignment, he was concerned with the development of machine design and specifications, a project which resulted in 1 granted patent. Purdue University granted Mr. Sheley the B.S.E.E. degree in 1930.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

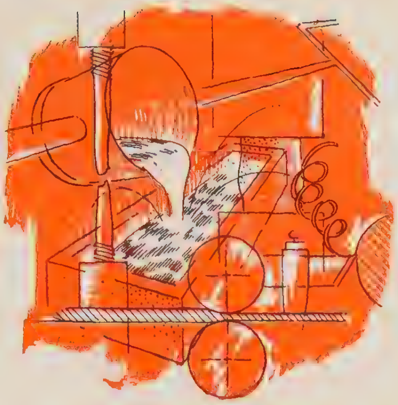
Mr. Todd is senior engineer at Delco-Remy. He was originally employed by Delco-Remy in March 1941 on assembly work in the Production Department. Subsequently, he was made junior designer in June 1943, senior designer in October 1944, and senior engineer in May 1953. He attended the University of Cincinnati. His current work is with plastic molding machines and heat sealing machines.

Mr. Goodwin is a senior machine designer in the Process Department of Delco-Remy. He was originally employed by Delco-Remy Battery Operations' Design Department in 1937 as a designer. Mr. Goodwin earned the B.S.M.E. degree from Purdue University in 1932. His past projects include work on the design and development of automatic commutator assembly machines and an automatic condenser winding machine.

• **James W. Jacobs,** *Frigidaire Division, Dayton, Ohio, for Refrigerating Apparatus, No. 2,724,241, issued November 22.* In this upright, home food freezing refrigerator cabinet, condensate is drained from an evaporator surrounding the liner of the food storage compartment thereof and directed into a removable receptacle mounted on the front wall of the cabinet and concealed by a hollowed-out lower portion of the compartment door. Access to the receptacle for detaching same from the cabinet and emptying water therefrom is obtained by opening the door.

• **James W. Jacobs,** *Frigidaire Division, Dayton, Ohio, for a Refrigerating Apparatus, No. 2,724,576, issued November 22.* In this patent, as the temperature of the room falls below 54° F, a series-heated bimetallic switch continuously closes and reopens, with an increasing proportion of closed time to open time, to energize the illuminating lamp in the food compartment of a 2-compartment refrigerator for causing sufficient operation of the refrigerating system to keep the freezer at 0° F.

• **James W. Jacobs,** *Frigidaire Division, Dayton, Ohio, for Refrigerating Apparatus, No. 2,729,720, issued January 3.* The refrigerator switch shown in this patent has a compensating diaphragm exposed to atmospheric pressure which diaphragm compensates for the effect of atmospheric pressure upon the actuating diaphragm.



Mr. Jacobs serves as a section engineer in the Kitchen Design Section of Frigidaire, where his recent work concerns the design and development of the "Holiday" kitchen. Joining Frigidaire as a draftsman in the Patent Department in 1937, Mr. Jacobs has worked subsequently in the fields of automobile air conditioning, household refrigeration, and, presently, kitchen appliances. He received the B.S.M.E. degree from University of Dayton in 1954.

• **Helmuth Guentsche, Laurence A. Nelson and Hans O. Schjolin,** *GMC Truck and Coach Division, Pontiac, Michigan, for Hydraulic Torque Converter, No. 2,724,292 and No. 2,724,293, issued November 22.* These 2 patents are for the angle drive transmissions of the type widely used on transit buses and in which the engine drives the angle shaft either through a speed-reducing hydraulic torque converter or alternatively through a direct mechanical connection. Both patents relate to refinements in the mechanical design of the transmissions.

Mr. Guentsche has been drafting supervisor in the Engineering Department of GMC Truck and Coach since 1945. He joined this Division in 1923, when it was known as the Yellow Cab Manufacturing Company. Currently his work concerns transmission development. The Technical University of Berlin in Charlottenburg, Germany, granted him a degree in engineering in 1923.

Mr. Schjolin has served as a new-development engineer in the GMC Truck and Coach Engineering Department since 1937. He was originally employed in October 1923 as a draftsman by Yellow Truck and Coach Manufacturing Company, Chicago. Mr. Schjolin received the B.S. degree from Karlstad University, Sweden, (1920) and Mitweida University, Germany, (1923).

Mr. Nelson is no longer with the Division.

• **John Dolza*,** *GM Engineering Staff, Detroit, Michigan, for Hydraulic Lash Adjuster, No. 2,724,373, issued November 22.* This patent relates to automatic adjustment of poppet valve tappet clearance in which the usual check valve is under direct thrust of the engine push rod.

• **John Dolza*,** *GM Engineering Staff, Detroit, Michigan, for Manifold Heat Control Valve, No. 2,725,862, issued December 6.* This patent relates to means for both baffling exhaust gases and controlling the combustible charge to an engine through the use of a heat control valve operatively connected to a thermostatically controlled choke mechanism.

• **Robert H. Wellman,** *Electro-Motive Division, LaGrange, Illinois, for Safety Cover Means for Internal Combustion Engines, No. 2,724,378, issued November 22.* This patent relates to venting of the engine crankcase via the accessory drive housing to a special blow-off cover so as to provide pressure relief in the event of explosions in the crankcase.

Mr. Wellman is a mechanical design engineer in the Engineering Department of Electro-Motive, where he began work in 1937 as a mechanical draftsman. In 1944 he became senior project engineer and assumed his present position in 1955. He is currently engaged in Diesel engine, gasifier, and turbocharger design work. Mr. Wellman received the B.S.M.E. degree from Northwestern University.

• **Albert P. Dinsmore,** *Aeroproducts Operations, Allison Division, Dayton, Ohio, for Speed Controller for a Prime Mover Driven Propeller, No. 2,724,445, issued November 22.* This invention relates to an electronic governor for controlling a variable pitch propeller including phase-sensitive means for detecting speed differences between a controlled propeller and a reference speed source wherein the controlled propeller includes centrifugally actuated means for shifting the phase of an alternating current signal in response to speed changes of the controlled propeller.

Mr. Dinsmore serves as a project and design engineer in the Engineering Department of Aeroproducts, where he is currently engaged in developmental work on supersonic propellers. He joined Aeroproducts in 1942 as a vibration tester and was appointed to his present position in 1946. His previous projects have included developmental work on electronic con-

trols. Mr. Dinsmore attended Miami University.

• **Frank W. Brooks,** *Moraine Products Division, Dayton, Ohio, for a Self-Adjusting Brake, No. 2,724,460, issued November 22.* This patent covers a duo-servo brake structure in which the brake shoes engage a member slidable on the anchor pin to provide for self centering of the shoes relative to the drum.

Mr. Brooks is a project engineer in the Engineering Department of Moraine Products. In 1935 he joined GM as an inspector at Delco Products, transferring to Delco's Engineering Laboratory the next year. Mr. Brooks transferred to Moraine Products' Engineering Department in 1942. He was granted the B.S. degree in mechanical engineering from Case Institute of Technology in 1935.

• **John M. Murphy,** *Frigidaire Division, Dayton, Ohio, for an Automatically Controlled Refrigerating Apparatus with Heating Means, No. 2,724,577, issued November 22.* This patent relates to a control system for a 2-temperature household refrigerator wherein the desired proper temperature differential is maintained in the freezing compartment and the unfrozen food storage compartment irrespective of temperatures ambient to the refrigerator cabinet. Should the temperature outside the cabinet fall below that within the unfrozen food compartment but above that in the freezing compartment, so as to require no refrigeration in the unfrozen food compartment, a heating means in the unfrozen food compartment is energized upon a subsequent demand for refrigeration in the freezing compartment to artificially heat the unfrozen food compartment and prevent freezing of foods stored therein.

Mr. Murphy is section engineer at Frigidaire where he is concerned with the development and design of rotary compressors. In 1930 he received the B.S.E.E. degree from Purdue University and joined GM Radio Corporation, transferring to Frigidaire in 1933. His work in the design of commercial and household compressor equipment and refrigerating units for household refrigerators has resulted in 5 granted patents.

• **Orson V. Saunders,** *Frigidaire Division, Dayton, Ohio, for Extensible Slides for Refrigerator Shelves, No. 2,724,630, issued November 22.* This is one of 2 patents obtained on Frigidaire's "roll-to-you" refrigerator cabinet shelves. A shelf may be extended part way or substantially all the way out of a food compartment as desired, while being supported from within the compartment against tilting.

Mr. Saunders is supervisor of the major product line in the Household Engineering Department at Frigidaire. Employed as a senior detailer in May 1936, he was promoted through the positions of layout draftsman, designer, senior layout man, experimental engineer, project engineer, senior project engineer, and section engineer to his present position.

• **George W. Onksen,** *Guide Lamp Division, Anderson, Indiana, for Resilient Headlight Mounting, No. 2,724,770, issued November 22.* This patent relates to a shock mounting for a tractor headlight in which a resilient rubber bushing permits a certain amount of lateral movement of the headlight without any undue rotational movement of the light.

• **George W. Onksen,** *Guide Lamp Division, Anderson, Indiana, for Vehicle Illumination System, No. 2,731,584, issued January 17.* This patent relates to the use of dimming resistors inserted in the stop and turn signal lamp circuits of a vehicle whenever the parking or headlamps are turned on, thereby permitting the use of warning lamps which are of sufficient brilliance for daytime operation and of reduced brilliance without glare at night.

Mr. Onksen is supervisor of research for Guide Lamp. He began his General Motors career in 1928 as an apprentice tool maker with Delco-Remy Division. After graduation from General Motors Institute in 1933, he joined the Guide Lamp Engineering Department. His major contributions have been in the fields of automotive headlamp lighting and automatic headlamp controls.

• **Elbert L. Johnson,** *Packard Electric Division, Warren, Ohio, for Connector, No. 2,724,812, issued November 22.* This patent is directed to a specific form of line connector and includes 2 interlocking connecting members formed of nylon or other suitable plastic into which conductors having contacts on their ends extend. A spring in one of the connecting members holds the contacts in engagement when the connecting members are locked together.

Mr. Johnson serves as head of ordnance engineering at Packard Electric. He began his career with GM in 1929, when he was employed by Delco-Remy Division. He was graduated from General Motors Institute in 1936. He transferred to Packard Electric in 1942, and in 194[illegible] he set up the Special Development Section directing this activity until he was appointed to his present post in 195[illegible]

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

• **Robert W. Leland*,** *Delco Products Division, Dayton, Ohio, for a Terminal Connector, No. 2,724,813, issued November 22.* This patent relates to a multiple terminal connector assembly for gang connection of terminals wherein each of the terminals is locked in a flat plate to form a gang connector.

• **Charles A. Sanft,** *Pontiac Motor Division, Pontiac, Michigan, for a Hand Brake Linkage, No. 2,724,982, issued November 2[illegible]* This patent relates to a linkage mechanism for the hand brake to increase the mechanical advantage, a flexible cable attached to the pull bar being carried over a pulley member on one end of bell crank lever.

Mr. Sanft is senior designer in the Engineering Department of Pontiac Motor. He joined General Motors in 1919 at GMC Truck and Coach and transferred to Pontiac Motor in 1928 as a draftsman. He assumed his present position in 1936. Mr. Sanft studied engineering for 2 years at The Ohio State University and served for 2 years in the United States Army.

• **Frank W. Gerard and Leo J. FitzHarris,** *Frigidaire Division, Dayton, Ohio, for an Applicator Tool, No. 2,725,089, issued November 29.* The tool shown in this patent has beneath the handle a set of rollers for guiding the tool along a bead. A thread guide directs an adhesive cord beneath one of the rollers onto the bead as the tool is moved along the bead.

Mr. Gerard is manager of air conditioning engineering at Frigidaire, where he began work in 1928 as a junior research chemist. Washington State College granted him the B.S. degree in 1927, and

in 1928 he received the M.S. degree from University of California. Mr. Gerard is a member of Tau Beta Pi and Phi Lambda Upsilon, honorary societies. Six patents have been granted as a result of his work.

Mr. FitzHarris is no longer with the Division.

• **Robert H. Spahr, Jr.,** *AC Spark Plug Division, Flint, Michigan, for Air Cleaner Retainer, No. 2,725,116, issued November 29.* This patent relates to an air cleaner and silencer assembly having the cleaner disposed within the silencer and retained in sealed relation thereto by unitary fastening means which also retains the sound absorbent material of the cleaner cover in spaced relation to the foraminous filter material.

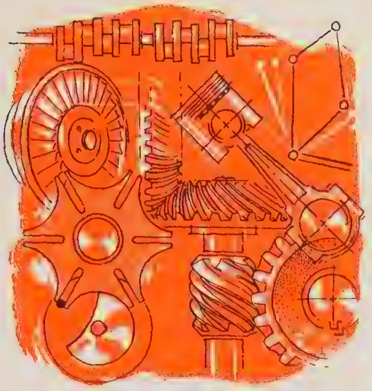
Mr. Spahr has been project engineer in the Experimental Engineering Department of AC Spark Plug since 1951. He joined AC in 1943 as a General Motors Institute co-op student, receiving the B.M.E. degree in 1949. His research work concerns engine intake silencers. Furthermore, he is responsible for sound laboratory operations; previously he worked on aluminum air cleaner and silencer design and development. Mr. Spahr is a member of the S.A.E.

• **Maurice A. Thorne,** *GM Engineering Staff, Detroit, Michigan, for a Hydraulic Line Seal, No. 2,725,122, issued November 29.* This invention relates to a seal structure placed in a hydraulic brake line at the juncture between a wheel hub and a brake spider to bridge the juncture and prevent leakage of hydraulic fluid.

Mr. Thorne has been engineer-in-charge of the Vehicle Development Group of the Engineering Staff since 1952. He joined the Engineering Staff in 1941 following 7 years with the Oldsmobile Division Engineering Department. During World War II, Mr. Thorne was chief engineer on the heavy tank M-26 and related pilot models at Fisher Tank Division. He received the B.A. degree from George Washington University in 1922.

• **William F. Holin,** *Electro-Motive Division, LaGrange, Illinois, for Brake Rigging, No. 2,725,124, issued November 29.* This patent relates to bifurcated railway brake hangers which stabilize the brake heads adjacent to the wheels.

Mr. Holin is a senior project engineer in the Engineering Department at



Electro-Motive. He has served with this Division for 20 years, starting as a draftsman in 1936. The majority of his design projects have been concerned with the development of railroad trucks, and his work has resulted in the grant of 5 patents. Mr. Holin's early technical education was in Konstanz, Germany.

• **Calvin J. Werner,** *Delco Products Division (now at Moraine Products Division), Dayton, Ohio, for a Finned Tail-Piece, No. 2,725,233, issued November 29.* This patent relates to a tail-piece for a projectile, the tail-piece being formed from a single metal sheet and bent to effect a tail formation having tail fins arranged at 90° angles.

Mr. Werner, general manager of Moraine Products, has over 30 years' experience with GM, having joined Delco Products in 1923 as a co-op student. He received his electrical engineering degree from University of Cincinnati in 1930. As the result of his work 59 patents have been issued in the fields of motor and control devices and shock absorbers. Mr. Werner is a member of the S.A.E., the Engineers Club of Dayton, and a Fellow of the A.I.E.E.

• **Philip W. Maurer* and William J. Tell,** *Cadillac Motor Car Division, Detroit, Michigan, for Wheel Covers, No. 2,725,257, issued November 29.* This patent relates to certain improvements in wheel cover attaching means.

Mr. Tell is no longer with the Division.

• **Ralph H. Mitchel* and Ralph O. Helgeby,** *AC Spark Plug Division, Flint, Michigan, for Temperature Compensation for a Magnetic Speedometer Drive, No. 2,725,493, issued November 29.* This patent pertains to a magnetic measuring instrument having a temperature-responsive compensator formed of an alloy consisting principally of iron, chromium, and nickel and containing small amounts of silicon and manganese. A speedometer equipped with this compensator provides highly accurate readings over an unusually wide range of temperatures.

Mr. Helgeby is a staff engineer at AC Spark Plug. He started with GM as a speedometer designer at AC in 1925. He holds a degree in mechanical engineering from Horten School of Technology (Norway) and studied business administration at General Motors Institute in 1926. One of Mr. Helgeby's most recent developments in speedometer design is the Redliner speedometer.

• **Yro T. Sihvonen,** *GM Research Staff, Detroit, Michigan, for Combustion Chamber Pressure Indicator, No. 2,725,501, issued November 29.* This invention relates to a combined spark plug and pressure indicator for use in testing internal combustion engines.

Mr. Sihvonen is a senior physicist in the Physics and Instrumentation Department of the Research Staff, where he is concerned with semiconductors, radiology, and specialized instrumentation problems. His work in the fields of emission and absorption spectrographic techniques and pressure transducers has resulted in 3 published papers. After attending General Motors Institute, Mr. Sihvonen received the B.S. degree from Antioch College in 1950 and the M.S. from University of Michigan in 1954.

• **Archie D. McDuffie,** *GM Research Staff, Detroit, Michigan, for Combustion Chamber, No. 2,725,865, issued December 6.* This invention involves a novel combustion chamber for engines embodying an arrangement of valves, ignition means, and chambers designed to provide for increased compression ratios.

Mr. McDuffie is an assistant department head of the Research Staff Automotive Engines Department. He began his GM career in 1931 at Cadillac Motor Car Division as a co-op engineering student from General Motors Institute. Upon graduation in 1934, he joined the Research Staff. Seven patents have issued from his work on combustion chamber development and high compression engines.

• **Michael Skunda,** *AC Spark Plug Division, Flint, Michigan, for Method for Shaping Ceramic Articles, No. 2,726,433, issued December 13.* This patent relates to a method for shaping ceramic articles by

using a cylindrical blank formed of ceramic material and a thermoplastic ingredient. While the blank is turned, it is engaged by a heated cutting tool to cut away portions of the blank to obtain the desired shape and subsequently fired to burn out the thermoplastic ingredient.

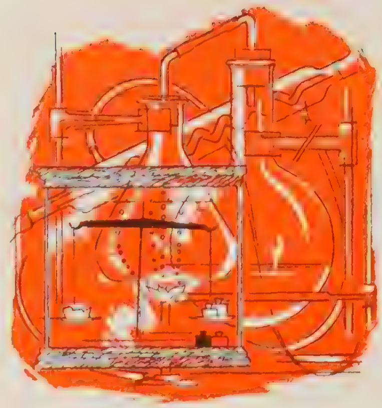
Mr. Skunda serves as supervisor of spark plug production engineering at AC Spark Plug, where he is responsible for the development of integrated equipment for spark plug manufacturing. His first position with the Division was as senior designer in the Gage Design Department in 1939. This is the second patent resulting from his developmental work on spark plugs.

• **August H. Borman, Jr., and Walter B. Herndon***, *Detroit Transmission Division, Ypsilanti, Michigan, for Transmission for an Automotive Vehicle, No. 2,726,746, issued December 13.* This patent relates to a combined manual and automatic transmission having 3 forward speeds and reverse. The manual part has sliding gears providing forward and reverse, and the automatic part provides second and high.

• **August H. Borman, Jr.**, *Detroit Transmission Division, Ypsilanti, Michigan, for Transmission Control System, No. 2,732,732, issued January 31.* This patent relates to an automatic transmission incorporating a torque converter driving a planetary gear unit with provision made for obtaining a direct drive between the engine and the output shaft.

Mr. Borman is a designer in the Engineering Department of Detroit Transmission, where he began work in 1941 as a detailer. He attended the Detroit Institute of Technology and Wayne University. At one time Mr. Borman worked on the design of hydraulic controls of experimental and production transmissions. These are the first patents granted as a result of Mr. Borman's work.

• **Robert A. Spaulding**, *Process Development Section, Detroit, Michigan, for Electroless Nickel Solution Control and Chemical Reduction Plating Process, No. 2,726,968 and No. 2,726,969, issued December 13.* These patents relate to improvements in electroless nickel plating. One patent concerns treating the plating bath with an anion exchange resin to remove impurities developed during the plating process, and in the other patent the nickel is replenished and the pH main-



tained by additions to the bath of various water and insoluble nickel compounds, such as nickel carbonate or nickel oxide.

Mr. Spaulding has been senior plating engineer in the Process Development Section of GM Manufacturing Staff since 1954, having joined this organization in 1950. He received the B.S. degree in chemical engineering from University of Illinois in 1943 and the M.S. degree from Purdue University in 1949, working with Delco-Remy Division in the interim. His work on electroless nickel plating has resulted in the grant of 2 patents.

• **Torsten G. Lillquist**, *Electro-Motive Division, LaGrange, Illinois, for Motor Cut-out Control, No. 2,727,195, issued December 13.* This patent concerns a locomotive control for isolating defective traction motors while at the same time readjusting the power connections of the remaining motors so as to prevent their overloading.

Mr. Lillquist is an electrical research engineer in the Engineering Department of Electro-Motive. His work in the field of Diesel locomotive electrical control systems has resulted in the grant of 16 patents. At present he is working on the development of an electrical torque converter. Mr. Lillquist joined Electro-Motive in 1927, progressing from draftsman, section engineer, and electrical controls engineer to his present position.

• **Robert R. Candor**, *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,727,315, issued December 20.* The laundry drier shown in this patent has a centrifugal switch operated by the drum driving belt which de-energizes the drier heater when the belt stops or breaks.

Mr. Candor is assistant patent counsel in the Dayton Office of the Patent Section. He was originally employed in 1925 at the Patent Section's office in Washington, D.C. Transferring as a patent attorney to the Patent Section at Frigidaire in 1928, he was promoted to supervisor of the Dayton Patent Office in 1952. The College of Wooster granted him the B.S. degree in 1912.

• **Oliver K. Kelley***, *Transmission Development, Detroit, Michigan, for Multiple Rotor Converter having Plural Impellers, No. 2,727,360, issued December 20.* This patent relates to the fluid mechanics of hydrodynamic qtorue converters and is directed to the arrangement and shape of the parts which determine the hydraulic circuit so as to provide desired improvements in the hydraulic torque multiplying characteristics.

• **Kenneth E. Snyder***, *Detroit Transmission Division, Ypsilanti, Michigan, for Automatic Transmission and Controls Therefor, No. 2,728,247, issued December 27.* This patent relates to hydraulic control systems of an automatic transmission wherein provision is made for assuring the proper timing between the release of a clutch and the application of a brake.

• **Paul J. Louzecky and Arne J. Hovde**, *Cleveland Diesel Engine Division, Cleveland, Ohio, for Engine Lubrication and Piston Cooling, No. 2,728,331, issued December 27.* This patent concerns pressure lubrication and cooling of an engine piston through passages in the connecting rod which are fed from drilled passages in the crankshaft in a manner to utilize maximum oil inertia effect in promoting flow.

Mr. Louzecky has been Mechanical Section engineer of Cleveland Diesel Engine since 1953. He joined Cleveland Diesel in 1935 as a technical engineer later serving as supervisor of the Special Problems Section and head engineer of the Technical Department. Mr. Louzecky was granted the B.S. and M.S. degrees from Case Institute of Technology in 1932 and 1933. His technical affiliations include the American Welding Society, the A.S.M.E., and the S.A.E.

Mr. Hovde is a design engineer in the Engineering Department at Cleveland Diesel. He has been engaged in Diesel engine design since 1929 with this Division and with its predecessor, the Winton Engine Company. He began as a draftsman and advanced through the positions of designer, layout man, senior layout man, and special design engineer. He was graduated from the Technical University of Norway in 1923.

Solution to the Previous Problem:

Determine the Output Torque of a Cam-Operated Indexing Mechanism for an Assembly Machine

By GUY F. SCOTT
Process Development
Section

Assisted by Elwood K. Harris
General Motors Institute

Smooth, vibration-free operation of an indexing assembly machine is dependent upon proper design of the cam-operated indexing mechanism. Proper design, in turn, depends upon carefully calculating the output torque required by the indexing drive. Another requirement for proper design is the correct specification of drive shaft diameter to insure that excessive twisting will not take place when the torque load is applied. This is the solution to the problem presented in the March-April 1956 issue of the GENERAL MOTORS ENGINEERING JOURNAL. The total output torque required of the indexing mechansim is *826.36 in-lb*. The diameter of the drive shaft required to prevent excessive twisting is *1.567 in*.

Polar moment of inertia and rolling friction must be considered

THE cam-operated indexing mechanism's design is based upon a cam having uniform acceleration and velocity curves (Fig. 1). The essential mathematical difference between angular acceleration and linear acceleration is one of units. For uniform angular acceleration (analogous to gravity in the linear case) the angular position of the cam Θ at any given time t is given by the forumla:

$$\Theta = \tfrac{1}{2} At^2 \qquad (1)$$

where A is the angular acceleration. The initial angular velocity and displacement are zero.

If n equals the number of cam-follower stops for 1 revolution, $2\pi/n$ equals the number of radians traveled in 1 indexing motion.

If a equals the cam indexing period, then $a/360$ equals the fraction of cam revolution during which indexing takes place.

During the acceleration period, the indexing motion is half completed and the angular position Θ of the cam equals $(2\pi/n)$ $(\tfrac{1}{2})$. The time t needed to complete one-half of the indexing motion equals $(a/360)$ $(1/N)$ $(\tfrac{1}{2})$, where N is the number of cam revolutions per second.

Substituting into equation (1) the values for Θ and t gives:

$$(2\pi/n)\ (\tfrac{1}{2}) = \tfrac{1}{2}A\,[(a/360)\ (1/N)\ (\tfrac{1}{2})].$$

Solving the above equation for the angular acceleration A gives:

$$A = 4\ (2\pi/n)\ (360N/a)^2. \qquad (2)$$

It is possible to calculate the angular acceleration A for any acceleration curve by integrating the angular acceleration to determine the angular velocity and then integrating the angular velocity to determine the angular displacement. Both integrations are between the limits of Θ and t, assuming initial condition of zero displacement and zero velocity.

Since the cam makes 1 revolution each index and the index time is 0.5 seconds, the cam must make 1 revolution in 0.5 seconds or 2 revolutions per second. Therefore, the maximum angular acceleration A from equation (2) is:

$$A = 4(2\pi/4)\ (360(2)/270)^2$$

$$A = 44.68 \text{ radians/sec}^2.$$

The total weight W of the carriers, product, and roller chain is equal to the weights W_1 plus W_2. The weight W_1 equals 90 carriers times 4 lb per carrier, or 360.00 lb. W_2 equals 90 carriers times 6 in. spacing between carriers times 1.95 lb per ft, or 87.75 lb. Therefore, the total weight W equals 447.75 lb.

The total polar moment of inertia J equals the sum of J_1, the polar moment of inertia of the carriers, product, and roller chain, plus J_2, the polar moment of inertia of the 4 sprockets.

The polar moment of inertia J_1 of the carriers, product, and roller chain is:

$$J_1 = (\text{total weight}/g)\ (\text{sprocket radius})^2$$

where

g = gravitational conversion factor (in. per sec²).

Substituting the known values for the total weight W, g, and the sprocket radius into the above equation gives:

$$J_1 = (447.75/386.4)\ (3.826)^2$$

$$J_1 = 16.96 \text{ in-lb-sec}^2.$$

The polar moment of inertia J_2 of the 4 sprockets is the sum of the polar moment of inertia J_h of each sprocket hub plus the polar moment of inertia J_b of each sprocket body.

The polar moment of inertia J_h of the sprocket hub can be calculated as follows:

$$J_h = 4\ (\pi r^4 ma/2)$$

where

4 = number of sprockets

r = sprocket hub radius (in.)

m = unit mass of sprocket (lb per cu in. per in. per sec²)

a = sprocket hub projection (in.).

Substituting the known values for r, m, and a into the above equation for J_h gives:

$$J_h = 4\,[(\pi)\ (2)^4\ (0.282/386.4)\ (1.409)/2]$$

$$J_h = 0.103 \text{ in-lb-sec}^2.$$

The polar moment of inertia J_b for the sprocket body can be calculated by the following equation:

$$J_b = 4\ (\pi r^4 ma/2)$$

where

4 = number of sprockets

r = pitch radius of sprocket (in.)

m = unit mass of sprocket (lb per cu in. per in. per sec^2)

a = tooth face (in.).

Substituting the known values for r, m, and a into the above equation for J_b gives:

$$J_b = 4[(\pi)(3.826)^4(0.282/386.4)(1.341)/2]$$

$$J_b = 1.318 \text{ in-lb-sec}^2.$$

The polar moment of inertia J_2 of the 4 sprockets is equal to the sum of J_h plus J_b or

$$J_2 = J_h + J_b = 0.103 + 1.318 = 1.421 \text{ in-lb-sec}^2.$$

The total polar moment of inertia J is equal to the sum of J_1 plus J_2 or

$$J = J_1 + J_2 = 16.96 + 1.42 = 18.38 \text{ in-lb-sec}^2.$$

The maximum inertia torque T_i required to accelerate and decelerate the inertia of the parts to be indexed is equal to the product of the total polar moment of inertia J times the maximum angular acceleration A or

$$T_i = (J)(A) = (18.38)(44.68) = 821.22 \text{ in-lb.}$$

The friction torque T_f, which also must be considered, can be calculated by the formula:

$$T_f = W\,C\,r \qquad (3)$$

where

W = total weight of carriers, product load, and roller chain (lb)

C = coefficient of rolling friction (0.003)

r = pitch radius of drive sprocket (in.).

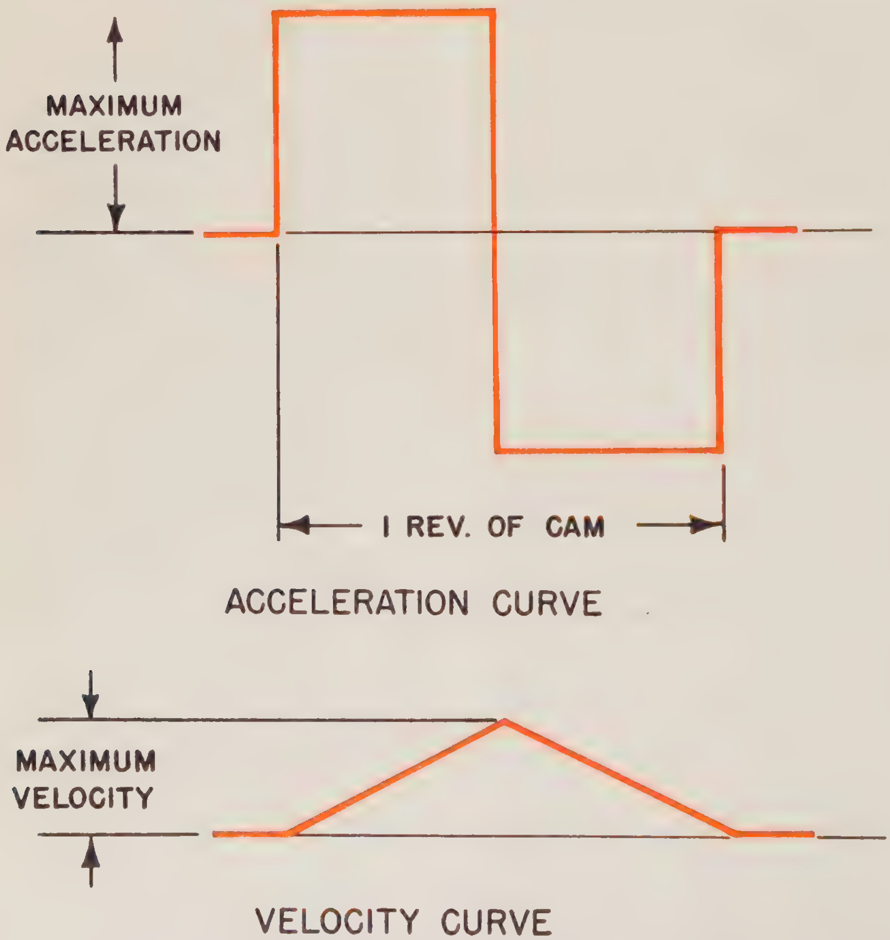


Fig. 1—The cams used in conjunction with an indexing mechanism are usually designed around either uniform, sine, cosine, triangular, isosceles, or trapezoid acceleration curves. The curves shown are for uniform acceleration.

Substituting into equation (3) the known values for W, C, and r gives:

$$T_f = (447.75)(0.003)(3.826) = 5.14 \text{ in-lb.}$$

The total output torque T required of the indexing mechanism is the sum of the inertia torque T_i plus the friction torque T_f or

$$T = T_i + T_f = 821.22 + 5.14 = 826.36 \text{ in-lb.}$$

The problem also called for determining the proper diameter of the drive shaft between the drive sprocket and the index cam follower so that it will be stiff enough to resist excessive twist when subjected to the torque-load application. The torsional deflection of the drive shaft can be expressed by the following equation:

$$a = 180Ml/IG\pi \qquad (4)$$

where

a = allowable angle of twist (degrees)

M = twisting moment of the torque load (in-lb)

l = length of drive shaft being twisted (in.)

I = polar moment of inertia of the shaft = $\pi D^4/32$ (in.^{4})

D = required diameter of the drive shaft (in.)

G = torsional modulus of elasticity (12,000,000 psi).

Substituting into equation (4) the value for I and then solving the resulting equation for D gives:

$$D = \sqrt[4]{180\,(Ml)\,32/\pi^2 Ga} \qquad (5)$$

Substituting into equation (5) the values for M, l, G, and a gives the required diameter D of the drive shaft as follows:

$$D = \sqrt[4]{\frac{(180)(826.36)(15)(32)}{(\pi^2)(12)(10^6)(0.08)}}$$

$$D = 1.567 \text{ in. or } 1\tfrac{9}{16} \text{ in.}$$

The preceding calculations make possible the selection of a commercially available cam-indexing mechanism of proper size.

A Typical Problem in Engineering:

)etermine the Overall Length ›f a Rigid Tube Connecting 2 ?oints on a Gas Turbine Engine

By WILLIAM J. ELLIOTT
Allison Division

and ERIK H. HALVARSON
General Motors Institute

Solve a problem in 3-dimensional space by algebraic vector analysis

igid tubing used as fuel and oil system piping on gas turbine engines for jet aircraft is esigned to connect designated points established by the overall engine design, clear all bstructions, and be as short in length as possible. In the design of such tubing a layout an first decides points of suitable intersection for straight portions of the tube and then timates suitable bending radii large enough for the tube to clear all obstructions in its ath. With this information as given data the final step is to specify the tube's configura-on in terms suitable for fabrication. The problem presented here is to determine the ngth of a tube connecting 2 points on a gas turbine engine using, as established data, e *xyz* coordinates of the tube's beginning and end points, the *xyz* coordinates designating e intersection of straight tube elements, and the radius of each bend in the tube.

THE DESIGN of rigid tubing used for fuel and oil system piping on gas ırbine engines presents a problem in alculating line and arc lengths and ngles between lines and planes in -dimensional space. The tube must con-ect 2 points on the engine and clear any bstructions, such as engine accessories, ı its path. The ultimate objective in the esign of such tubing is to specify the ıbe's configuration in terms suitable for ıbrication.

The layout of the engine serves as the asis from which the line path of the rigid ıbe is defined by the coordinates of its eginning and end points, the coordinates f the intersection of each pair of straight ıbe elements, and the bending radius etween each pair of straight tube lements.

Problem

A rigid tube (Fig. 1a) is to be used to ›nnect 2 points A and D on a gas ırbine engine. The tube is bent at points and C in order to clear obstructions in s path. The fabrication procedure calls rst for straight-tube stock to be cut to a pecific length designated by design speci-cations. This length takes into consider-ion the straight and bent portions of e tube. The tube is then bent through a ertain angle around a drum (Fig. 1b) to ıake the first required bend at point B. he radius of the drum is the required end radius minus ½ the tube diameter. (All measurements are taken relative to the centerline of the tube.) The portion of tubing containing the first required bend is then rotated through a specified twist angle (Fig. 1d) about the segment of the tube which preceeds the next bend. When this step has been completed, the next bend at point C is made.

To determine the total length of tubing connecting points A and D requires calculation of the bending angles between pairs of adjacent straight tube elements, twist angles between planes, and the lengths of each straight and bent portion of the tube. The sum of the individual lengths gives the required total tube length.

At Allison Division all calculations relating to tubing are presented in a standard form for consistent orientation and are computed in a standard manner. For example, when looking along a tube from its front to rear (A to D, Fig. 1d), all bends in the tube from 0° to 360° are made to the right. Presenting computed data in a standard form saves an estimated 30 per cent in the total drafting time required for tubing layout work. Computations are performed by electronic calculators, which compute all information needed for 1 bend in 1 minute.

The problem is to determine the total length of tubing required to connect points A and D. The x, y, and z coordinates of the tube's beginning and end points and the intersection of the tube's straight portions in inches are as follows:

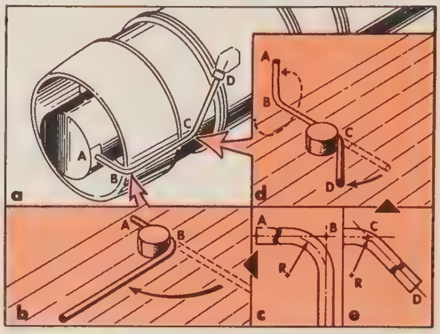
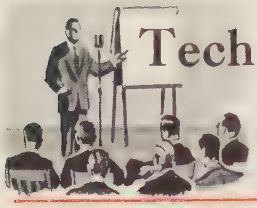


Fig. 1—The line path of a rigid tube connecting 2 points on a gas turbine engine (a) is defined by the *xyz* coordinates of its beginning and end points, A and D respectively; the *xyz* coordinates locating the intersection of its straight elements at points B and C; and the radius of bending between the tube's straight elements. The first step in the fabrication of a straight piece of tubing which has been cut to an exact length requires bending around a drum (b) to generate the first bend of required radius R (c) for the tube at point B. The portion of the tube containing the first bend is then rotated through a specific angle of rotation (d) about the segment of the tube which precedes the next bend. The tube is then bent around a drum to generate the final bend of required radius R (e) at point C.

- Point A (0, 0, 0)
- Point B (0, −1, 2)
- Point C (5, −1, 2)
- Point D (7, 2, −1)

The radius of bending R at point B (Fig. 1c) and point C (Fig. 1e) is equal to 1 in.

A solution to the problem may be obtained graphically or by algebraic vector analysis. Vector analysis will be used as the basis for presenting the solution to the problem which will appear in the October-November-December 1956 issue of the GENERAL MOTORS ENGINEERING JOURNAL.



Technical Presentations by GM Engineers

Technical papers presented by General Motors engineers, as well as lectures before college engineering classes and speaking appearances before other groups, further the objective of making available to the public current information about GM engineering developments. Listed below are some of these speaking engagements filled recently by GM engineers. In some cases, extra copies of the papers mentioned are available. Engineering educators who wish to request copies of papers listed may write either to the GM organization where the author is located or to Educational Relations Section, Public Relations Staff, General Motors Technical Center, P.O. Box 177, North End Station, Detroit 2, Michigan.

Aeronautical

Dean K. Hanink, chief metallurgist in the Metallurgy Department of Allison Division, presented "Ring Applications on the J33 Engine and Some Considerations in the Specifications for Materials and Processes" at the Happenstall Steel Company in Indianapolis, Indiana, on January 9. On January 10 at the Annual Meeting of the Society of Automotive Engineers held in Detroit, Michigan, Mr. Hanink presented "Engineering Requirements for Jet Engine Materials."

In Chicago, Illinois, on January 20 at a meeting of the Institute of Radio Engineers Industrial Group, **Karl F. Wacker** presented "Instrumentation Systems for Jet Engine Testing." Mr. Wacker is an experimental engineer in the Electronic and Parts Test Department of Allison Division.

"Arc Method for Sample Transfer in Spectro-analysis" was the title of a talk given by **Carl J. Leistner** on February 14 at a meeting of the Local Section of the American Chemical Society at Indianapolis, Indiana. Mr. Leistner is an experimental chemist in the Material Laboratory of Metallurgy at Allison Division.

On February 17 at a meeting of the Aeronautical Engineering Staff held at Purdue University, Lafayette, Indiana, **Thomas R. Heaton** presented "The Turbine in the Gas Turbine Engine." Mr. Heaton is senior project engineer in the Aircraft Engines Advanced Design and Development Department of Allison Division.

On February 29 **R. K. Louden** presented "Functions of the Aeronautical Engineer in the Automotive Industry" before the University of Detroit Chapter of the S.A.E. in Detroit, Michigan. Mr. Louden is project engineer in the Transmission Development Section of the GM Engineering Staff.

At a meeting of the Metropolitan Section of the S.A.E. held in New York, New York, on March 1 **Floyd G. Dougherty** presented "General Fuel Requirements for the Commercial Aircraft Turbine Engines." Mr. Dougherty is chief of the Aircraft Engines Combustion Section of Allison Division.

At the same meeting **Max C. Hardin**, supervisor of Aircraft Engines Fuels, Lubricants, and Basic Combustion Department of Allison Division, presented a talk entitled "Lubrication Requirements of the Turbo-Prop Engine." On March 14 Mr. Hardin presented "Fuels and Lubricants Requirements for the Commercial Turbo-Prop Engine" before a meeting of the Philadelphia Section of the S.A.E. held in Philadelphia, Pennsylvania.

In Chicago, Illinois, on March 8 **Francis E. Conn** presented "Aeroproducts Model 606 Turbo-Propeller" before a meeting of the Airline Pilot's Association. Mr. Conn is project engineer in the Engineering Design Department of Aeroproducts Operations of Allison Division.

Automotive

Floyd Wyczalek, supervisor in the Automotive Engines Department of the GM Research Staff, spoke before the Georgia Section of the S.A.E. in Atlanta, Georgia, on January 9. The title of his talk was "Mechanical Octanes for Higher Efficiency."

H. A. Reynolds, supervising engine in the Radiator Section of the Produ Engineering Department of Harris Radiator Division, spoke on "Radiat Cooling Development" at a meeting the Buffalo-Rochester Section of th S.A.E. held in Rochester, New York, o January 25. On January 10 Mr. Reynol presented "Effect of Fan Design on Coo ing Index, Horsepower, and Noise" a the Annual Meeting of the S.A.E. i Detroit, Michigan.

H. Flynn, staff engineer of the Truc Chassis Department of Chevrolet Moto Division, spoke before the S.A.E. at th Statler Hotel in Detroit, Michigan, o January 11. The title of his talk was " New Automatic Transmission for Heav Duty Chevrolet Trucks."

W. K. Steinhagen, staff engineer in th Power Development Section of the GM Engineering Staff presented "Automo tive Engineering" before the Fostori Engineer's Club in Fostoria, Ohio. Th meeting was held on January 11.

The Annual Meeting of the S.A.E held on January 12 at the Sheraton Cadillac Hotel in Detroit, Michigan, wa the occasion for a talk entitled "Th New Dynaflow Automatic Transmission presented by **Rudolph J. Gorsky**. M Gorsky is staff engineer in the Transm sion Department of Buick Motor Divisio

On January 19 at a meeting of th Highway Research Board in Washingto D.C., **R. J. Wirshing** presented "Effe of De-icing Salts on the Corrosion o Automobiles." Mr. Wirshing is head o the Chemistry Department of the GM Research Staff.

"Vehicle Vibration and Stress Test ing" was the title of the talk presente by **H. W. Larsen** at a meeting of th Chicago Section of the Society fo Experimental Stress Analysis held i Chicago, Illinois, on January 26. Mr Larsen is senior project engineer in th Noise and Vibration Laboratory of GM Proving Ground.

K. A. Stonex, head of the Technica Data Department at GM Provin Ground, presented a talk entitled "Auto motive Test Track Design" before th Highway Research Board in Washing ton, D.C., on January 17. On January 1 he presented "Effect of Governors o Passenger Car Performance" before th same group. "Passenger Car Charac teristics Observed at General Moto Proving Ground" was the title of a tal which Mr. Stonex presented on Februar

8 at a meeting of the Regional Highway Advanced Training Program at University of Maryland, College Park, Maryland.

On March 23 **P. C. Skeels,** head of the Experimental Engineering Department at GM Proving Ground, spoke at a meeting of the Detroit Section of the Society for Experimental Stress Analysis in Detroit, Michigan. The title of his talk was "The Use of Strain Gages in Automotive Test Work."

On February 15 Mr. Stonex, Mr. Skeels, and **E. A. Finney,** research engineer for the Michigan State Highway Department, presented "Road Surface Friction from the Standpoint of Automotive and Highway Engineers" at a meeting of the Association of Asphalt Paving Technologists. The meeting was held at Cleveland, Ohio.

At a meeting of the Society of Plastic Industries at the Chalfonte-Haddon Hall in Atlantic City, New Jersey, on February 7 **J. G. Coffin** presented a talk entitled "Laboratory Results versus Serviceability for Reinforced Plastic in Automobiles." Mr. Coffin is assistant materials engineer at Chevrolet Motor Division.

The meeting of the San Francisco Bay Area Chapter of the S.A.E. at San Francisco, California, on February 7 was the occasion for a talk entitled "The Spectacular New Hydra-Matic Drive" presented by **Thomas E. Dolan.** Mr. Dolan serves as staff engineer in the Engineering Department of Detroit Transmission Division.

At a joint meeting of the American Society of Refrigerating Engineers and the American Society of Heating and Air Conditioning Engineers held at St. Louis, Missouri, on February 9 **L. A. Zwicker** presented "Future Trends in Automotive Air Conditioning." Mr. Zwicker is assistant chief engineer in the Product Engineering Department of Harrison Radiator Division.

A meeting of the student section of the S.A.E. at Yale University, New Haven, Connecticut, on February 15 was the occasion for a talk by **Max M. Roensch,** director of Chevrolet Experimental Laboratories at Chevrolet Motor Division. The title of his talk was "The Chevrolet V-8 Engine."

On February 20 **George A. Delaney** presented "Designing an Automobile" before a meeting of the Montreal Section of the S.A.E. in Montreal, Canada. He presented this same talk before the Cincinnati Section of the S.A.E. at Cincinnati, Ohio, on February 27 and again on March 21 at a meeting of the Toronto Section of the S.A.E. Mr. Delaney is chief engineer of Pontiac Motor Division.

On February 23 **E. N. Cole,** chief engineer of Chevrolet Motor Division, spoke at a "Panel on Safety" at the Downtown Kiwanis Club held at the Durant Hotel in Flint, Michigan. On March 26 Mr. Cole acted as moderator of a discussion on "Stock Car Competition" at a meeting of the S.A.E. at the Rackham Educational Memorial, Detroit, Michigan.

At the same meeting of the S.A.E. **M. Rose** participated in the discussion with a talk entitled "Body and Chassis—Aspects of Stock Car Competition." Mr. Rose is special engine and vehicle development engineer in the Product Information Department of Chevrolet Motor Division.

"Combating Corrosion" was the title of a talk presented by **L. C. Rowe** before a meeting of the American Society of Body Engineers held in Detroit, Michigan, on February 23. Mr. Rowe is senior research chemist in the Chemistry Department of the GM Research Staff.

"1956 Dynaflow Transmission" was the title of a speech presented by **Robert S. Trembath,** project engineer in the Transmission Department of Buick Motor Division. The occasion was a meeting of the Student Branch of the S.A.E. held at Michigan State University in East Lansing, Michigan, on February 28.

At the General Electric Acoustics Seminar at Schenectady, New York, on March 8 **David C. Apps** presented "Some Automotive Noise Problems." Mr. Apps is head of the Noise and Vibration Laboratory at GM Proving Ground.

In Detroit, Michigan, at a meeting of the S.A.E. on March 8 **D. R. Whitney** presented a talk entitled "Unmeasurable Factors of Passenger Car Noise." Mr. Whitney is senior research engineer in the Special Problems Department of GM Research Staff.

"The 1956 Hydra-Matic Transmission" was the title of a talk given by **Darren H. Sand** before a meeting of the S.A.E. at Lansing, Michigan, on March 12. Mr. Sand is assistant staff engineer in the Engineering Department at Detroit Transmission Division.

"1956 Engines and Their Fuels" was the title of a talk presented by **J. D. Caplan** at a meeting of the Chicago Section of the S.A.E. held in Chicago, Illinois, on March 15. Mr. Caplan is assistant head of the Fuels and Lubricants Department of the GM Research Staff.

A meeting of the General Motors Institute Student Chapter of the S.A.E. on March 15 held at the Fisher's Hotel in Frankenmuth, Michigan, was the occasion for a talk entitled "Steering Linkages" presented by **D. P. Marquis.** Mr. Marquis is assistant chief engineer of Saginaw Steering Gear Division.

"Steering Mechanisms and How They Got That Way" was the title of a talk presented by **C. W. Lincoln** on January 13 before the 1956 Annual Meeting of the S.A.E. held at the Sheraton-Cadillac Hotel, Detroit, Michigan, and again on March 15 before the student chapter of the American Society of Mechanical Engineers at Purdue University in Lafayette, Indiana. Mr. Lincoln is chief engineer of Saginaw Steering Gear Division.

Bearings

Leland D. Cobb, manager of research and development in the Product Engineering Department of New Departure Division, presented "Advanced New Departure Research" before a group of engineer-customers at the GM Training Center in Burbank, California, on January 9. On January 10 he presented "New Departure Seals" at a meeting of the American Society of Lubrication Engineers at Los Angeles, California. At a meeting of the Northern Section of the A.S.L.E. at Berkley, California, on January 12 Mr. Cobb presented a talk entitled "New Departure Research," and on January 18 he presented this same talk at a meeting of the Coordinating Research Council at New Departure in Bristol, Connecticut.

A meeting of a group of engineer-customers held at New Departure in Los Angeles, California, on January 9 was the occasion for a talk entitled "Mounting and Lubrication Systems for Small Motors and Turbines Operating at High Speed and High Temperature" presented by **Heinz Hanau.** Mr. Hanau is supervisor of aircraft projects in the Product Engineering Department of New Departure Division.

At the same meeting **P. J. Baker** spoke on "High Speed, High Temperature Accessory Turbine Testing." Mr Baker is project engineer on the turbine

bearing program in the Product Engineering Department of New Departure Division.

On January 18 **R. J. Valentine**, aircraft project engineer in the Product Engineering Department of New Departure Division, spoke on "Aircraft Bearing Applications" before the C.R.C. at New Departure in Bristol, Connecticut. Mr. Valentine spoke on this topic again on March 8 at a Sales Symposium at Vertol Aircraft in Morton, Pennsylvania.

At a meeting of the C.R.C. at New Departure in Bristol, Connecticut, on January 18 **D. O. Wilson** presented "High Speed, High Temperature Bearing Research." Mr. Wilson is aircraft recommendation engineer in the Product Engineering Department of New Departure Division.

Diesel Engines and Off-The-Road Equipment

In Dallas, Texas, at the January 19 meeting of the Dallas Section of the A.S.M.E. **Bert H. Hefner** presented "Application of Electro-Motive Diesel-Electric Power to Oil Well Drilling Inland and Offshore Operations." Mr. Hefner is chief electrical engineer in the Engineering Department of Electro-Motive Division.

"TC-12 Crawler Tractor Development" was the title of a talk presented by **Don Graham** before the Houston Chapter of the S.A.E., Houston, Texas, on February 10. Mr. Graham is chief application engineer in the Sales Development Department of Euclid Division.

On February 17 at a meeting of the Philadelphia Section of Naval Architects and Marine Engineers in Philadelphia, Pennsylvania, **Eric R. Brater** presented a talk entitled "Application of Diesel Engines for Marine Service." Mr. Brater is assistant chief engineer in the Engineering Department of Cleveland Diesel Engine Division.

Electronics

On January 27 **Olin Lee**, logging representative in the Sales Development Department of Euclid Division, spoke before the sophomore class of electrical engineers at the University of Washington. The title of his speech was

"Recent Development in Magnetic Amplifiers."

D. E. Brinkerhoff and **W. E. See** presented a joint discussion on "High Fidelity Sound Reproduction" before an Area Conference of the Kokomo Foremen's Club in Kokomo, Indiana, on February 18. Both Mr. Brinkerhoff and Mr. See are project engineers in the Engineering Acoustics Department of Delco Radio Division.

Robert B. Colten, senior project engineer in the Electronics Department of the Process Development Section, GM Manufacturing Staff, spoke before the automation class at the Materials Management Center at Wayne University, Detroit, Michigan, on March 12. The title of this talk was "Electronic Control Elements."

Foundry

On February 20 **C. E. Fausel**, superintendent of maintenance in the Maintenance Department of Central Foundry Division, addressed the American Foundrymens Society in Rock Island, Illinois. His talk was entitled "Controlled Maintenance and Mechanization."

Harold G. Sieggreen presented "Applications of Shell Molding for the Auto Industry" before the S.A.E. in Cleveland, Ohio, on March 19. Mr. Sieggreen is chief engineer of Central Foundry Division.

R. F. Thomson presented "Planning for the Twentieth Century Foundry" at a meeting of the American Foundrymens Society held at Chicago, Illinois, on March 21. Mr. Thomson is head of the Metallurgical Engineering Department of the GM Research Staff.

General

On January 5 **Leonard Batz**, design engineer in the Design and Standards Section of AC Spark Plug Division, presented a talk entitled "Engineering for You" before a meeting of the De Volente Chapter of the American Business Women's Association held at the Masonic Temple in Flint, Michigan. On February 21 before a meeting of the Flint Shrine Club at the Masonic Temple in Flint, he presented "Engineering—A Dynamic Profession." On March 12 Mr. Batz presented the same talk before a meeting of the Civitan Club at the Hotel Durant in Flint and again on March 14 at a meeting of the Rotary Club held at the City Club in Owosso, Michigan. A meeting of the South Flint Kiwanis Club held at Bishop Airport, Flint, Michigan, on February 22 was the occasion for a talk entitled "Engineering—For a Brighter Future" given by Mr. Batz. He presented this same speech on March 21 before a meeting of the Fenton Kiwanis Club held at Lake Fenton, Michigan. "Conservation Through Standardization" was the title of a talk which Mr. Batz presented at a Conservation Symposium sponsored by the Detroit Air Procurement District, Mobile Air Materiels Area in Dearborn, Michigan, on March 29.

"New Departure Bicycle Products" was the title of a talk presented by **James D. Marsele** for the personnel of Westfield Manufacturing Company in Westfield, Massachusetts, on January 5. He presented this same talk again on February 14 before a group of bicycle jobbers and dealers at the Morrison Hotel in Chicago, Illinois. Mr. Marsele is bicycle products project engineer in the Product Engineering Department of New Departure Division.

In Chicago, Illinois, on January 10 at a meeting of the American Spectrographers **D. L. Fry** spoke on "What Are We Worth." Mr. Fry is supervisor of the Physics and Instrumentation Department of the GM Research Staff.

At the Hotel Statler in Cleveland, Ohio, on January 19 **Donald H. Lewis** presented "Automatic Plastic Molding" at a meeting of the Society of Plastics Engineers. Mr. Lewis is supervisor of chemical-plastic die casting in the Tool and Process Engineering Department of Packard Electric Division.

At a meeting of the Rochester Chapter of the A.S.M.E. at Rochester, New York on January 26 **V. H. Hardy** participated in a panel discussion on "Counselling Young Engineers." Mr. Hardy is as

sistant chief engineer in the Product Engineering Department of Delco Appliance Division.

At the same meeting **Henry Mowers** participated in the panel discussion. Mr. Mowers is supervisor of Process Development at Rochester Products Division.

Robert M. Wagner discussed Buick's experience during World War II and the Korean conflict in conversion of plants from civilian to military production and reconversion back to peacetime work at a special seminar on economic mobilization of the automotive industry at the Industrial College of the Armed Forces in Washington, D. C., on January 30. Mr. Wagner is general production manager of Buick Motor Division.

In Columbus, Ohio, on February 1 **R. P. Koehring** presented "Powder Metallurgy" before a meeting of the Columbus Chapter of the American Society for Metals. Mr. Koehring is section engineer in the Engineering Department of Moraine Products Division.

Francis E. Smith, senior staff assistant in the Design and Drafting Department of Fisher Body Division spoke at St. Catherine's High School in Detroit, Michigan, on February 1. The title of his talk was "Job Opportunities in the Engineering Field."

"What Industry Expects of College Graduates and Professional Development" was the title of a talk presented by **Edward J. Bentley** before a meeting of the American Institute of Electrical Engineers Student Affiliate at Cookeville, Tennessee, on February 3. Mr. Bentley is supervisor of college relations in the Personnel Department of Delco Products Division.

A meeting of the Society of Plastics Industry held in Atlantic City, New Jersey, on February 7 was the occasion for a talk by **G. L. Leithauser,** research chemist in the Chemistry Department of the GM Research Staff. The title of his talk was "Post-Finishing Polyester Plastics."

Howard W. Brandt, general manager of Rochester Products Division, represented industry in a panel discussion on "Meeting Our Skilled and Technical Manpower Requirements" at a joint school-industry dinner meeting of the Industrial Management Council of Rochester, New York, on February 13.

Robert Chase, supervisor of Product Engineering at AC Spark Plug Division, addressed the Flint Grapho-Analysis Club on February 13 on his experiences in using handwriting analysis in interviewing of engineers for employment. This meeting also consisted of a staged interview and question and answer session. On February 21 he addressed the West Flint Kiwanis Club with a talk entitled "The Engineer's Role in America." Mr. Chase acted as toastmaster at an intersociety dinner meeting of all engineers held at Ballenger Field House in Flint, Michigan. On March 28, Mr. Chase was a member of a panel discussion "New Horizons in Electronics" before the Science Club at Flint Technical High School.

A meeting of the Euclid Rotary Club held at Euclid, Ohio, on February 20 was the occasion for a talk entitled "American Road Building Needs" presented by **Phil Neppel.** Mr. Neppel is service training supervisor in the Service Department of Euclid Division.

H. C. Rohr, chief engineer of Delco Appliance Division, spoke before a meeting of the Rochester Chapter of the A.S.M.E. at Rochester, New York, on March 12. The title of his presentation was "Maintaining a Professional Interest and High Productivity with Engineers."

"Industry—Its Place in the Community" was the title of a talk presented by **W. L. Mautz** at a meeting of the Parent-Teacher Association at the Christiancy School, Lansing, Michigan, on March 13. Mr. Mautz is chief inspector of the Forge Inspection Department of Oldsmobile Division.

"Spectrographic Computers" was the title of a talk presented by **John S. Wolfe** before the Niagara Frontier Section of the Optical Society of America in Lockport, New York, on March 14. Mr. Wolfe is a chemist in the Engineering Department of Delco Products Division.

C. D. Harrington, administrative engineer in the Product Engineering Department of Oldsmobile Division, spoke at Belding High School in Belding, Michigan, on March 21. The title of his talk was "Mechanical Engineering."

Before a meeting of the Oakland County Chapter, Michigan Society of Professional Engineers, held at the Waldron Hotel, Pontiac, Michigan, on March 22 **John Burnell** presented "The Design and Development of an Engineer." Mr. Burnell is a design engineer in the Engineering Department of the Chevrolet Motor Division.

A conference of College Composition and Communication held in New York on March 24 was the occasion for a speech entitled "Listening Comprehension" presented by **Roger Hamlin.** Mr. Hamlin is an instructor of speech at General Motors Institute, Flint, Michigan.

Before a session of the Beaver Creek High School advanced algebra class in Dayton, Ohio, on March 26 **John T. Price** spoke on "The Co-operative System of Education in Engineering." Mr. Price is test engineer in the Engineering Laboratory of Delco Products Division.

"Driver Training" was the title of a talk presented by **M. Rose** before 4,000 high school students, police, and civic authorities at the Buffalo Memorial Building, Buffalo, New York, on March 26. Mr. Rose is special engine and vehicle development engineer in the Product Information Department of Chevrolet Motor Division.

Manufacturing

"How to Train Engineers for Manufacturing" was the title of a panel discussion in which **Robert T. Weiser** participated on November 14 before a meeting of the A.S.M.E. held in Chicago, Illinois. Mr. Weiser is personnel director of Rochester Products Division.

Claude M. Willis, safety director of the Safety Department of Delco Products Division, presented a talk entitled "Common Sense of Safety" before the Foremen's Club in Dayton, Ohio, on January 18. On February 2, Mr. Willis presented a talk entitled "Job Analysis, Inspection, Investigation, Layout, Housekeeping" before a safety class sponsored by the Chamber of Commerce in Dayton.

On January 24 **Robert B. Taylor** acted as moderator in a panel discussion on "Establishing and Maintaining Indirect Labor Standards" before the industrial engineering group of the Industrial Management Council of Rochester, Rochester, New York. Mr. Taylor is supervisor of Standards for Rochester Products Division.

Before a meeting of the Safety Council of the Chamber of Commerce of Dayton, Ohio, on February 8 **Robert F. Dunham** discussed "Safety Factors in the Selection and Maintenance of Industrial Trucks." Mr. Dunham is supervisor of material handling in the Shipping and Receiving Department of Delco Products Division.

On February 10 **Joseph Hovespian,** a process engineer in the Product Engineering Activity of Fisher Body Division, presented a speech entitled "Die Casting" before a meeting of the Boys' Club at Wayne University in Detroit, Michigan.

"Basic Approach to Progress in Mechanization" was the title of a talk presented by **John Mahan** before a meeting of the American Society of Tool Engineers in Frankenmuth, Michigan, on February 16. Mr. Mahan is an instructor of industrial engineering at General Motors Institute, Flint, Michigan.

A meeting of the automation class at the Materials Management Center at Wayne University, Detroit, Michigan, on February 20 was the occasion for a speech by **Ward F. Diehl,** senior project engineer in the Engineering Department of the Process Development Section, GM Manufacturing Staff. "Hydraulics Maintenance, Standards, Planning, and Purchasing Relative to Automation Work" was the title of his talk.

On Feburary 21 **Alfred H. Ellinwood,** methods engineer in the Methods Engineering Department of Oldsmobile Division, spoke before the Michigan State University Student Chapter of the A.S.M.E. in East Lansing, Michigan. The title of his talk was "How We Plan to Manufacture a New Product at Oldsmobile."

On February 27 **Robert D. McLandress,** director of the Work Standards and Methods Engineering Section of the GM Manufacturing Staff, participated in a panel discussion on "How to Create Job Interest Through Methods" before a meeting of the Society for Advancement of Management. The meeting was held at the Rackham Educational Memorial in Detroit, Michigan.

Robert E. Beaman presented a talk entitled "Work Sampling" before the Toledo Chapter of the A.I.E.E. in Toledo, Ohio, on February 28. Mr. Beaman is supervisor of work standards in the Standards Department of Delco Products Division.

David Waldshan presented "Industrial Organization" before the industrial engineering class at Wayne University, Detroit, Michigan, on March 1. Mr. Waldshan is a process engineer in the Product Engineering Activity of the Fisher Body Division.

"What We Expect of the Machine Tool Builder" was the title of a talk presented by **John Q. Holmes** before the Cleveland Engineering Society in Cleveland, Ohio, on March 5. Mr. Holmes is supervisor of equipment and operations in the Production Engineering Section of the GM Manufacturing Staff.

On March 8 **P. E. Cartwright,** director of standards, methods, and plant layout at Detroit Transmission Division presented "7 Point Program of Cost Reduction at Detroit Transmission Division" before the Time Study Engineering Society of Detroit. The meeting was held in Detroit, Michigan.

A meeting of the Midland Engineers' Club held in the Oldsmobile Auditorium in Lansing, Michigan, on March 13 was the occasion for a talk by **Robert T. Rollis** entitled "Manufacturing at Oldsmobile." Mr. Rollis is general manufacturing manager of Oldsmobile Division.

Before a meeting of the A.S.M.E. held at the University of Missouri, Columbia, Missouri, on March 20 **James U. Ard** presented a talk entitled "Challenges of Automotive Assembly Plant for the Mechanical Engineer." Mr. Ard is general foreman of the Chassis Department of Buick-Oldsmobile-Pontiac Assembly Division.

At a meeting of the Midwest Section of the American Welding Society held at Indianapolis, Indiana, on March 23 **J. A. Blastik** presented a talk entitled "Maintenance Welding at Oldsmobile." Mr. Blastik is welding engineer in the Production Engineering Department of Oldsmobile Division.

Research

E. F. Weller and **R. R. Bockemuehl** jointly presented "An Instrument for Recording Cylinder Pressure versus the Crank Angle of an Internal Combustion Engine" before a meeting of the Fuels and Lubricants Activity Section of the S.A.E. in Detroit, Michigan, on January 12. Mr. Weller is assistant head of the Physics and Instrumentation Department, GM Research Staff, and Mr. Bockemuehl is a research engineer in the same Department.

A meeting of the Cleveland Section of the S.A.E. held in Cleveland, Ohio, on January 16 was the occasion for a speech by **S. R. Rouze,** research physicist in the Physics and Instrumentation Department of the GM Research Staff. The title of his talk was "Study of Detergency in Lubricating Oils by Electron Microscopy."

"Toward Better Plating" was the title of a talk presented by **C. F. Nixon,** head of the Electro-Chemistry Department of the GM Research Staff, on February 1 in Atlanta, Georgia. The occasion for the talk was a meeting of the American Electroplaters Society.

L. L. Withrow presented "Some Problems Associated with the Recommendation and Use of Multi-Viscosity Oils" before the American Petroleum Institute in Detroit, Michigan, on February 28. Mr. Withrow is head of the Chemistry Department of the GM Research Staff.

The General Electric Vibration and Fatigue Seminar held in Schenectady, New York, on March 15 was the occasion for a talk presented by **R. L. Mattson,** assistant head of the Engineering Mechanics Department of the GM Research Staff. The title of his talk was "Fatigue and Residual Stresses."

Reprints Available

Engineering educators desiring reprints of papers published in the General Motors Engineering Journal may direct requests to the editor. Requests involving a small number of reprints are filled by supplying copies of the entire magazine. When requests are in larger numbers, reprints may be made. Copies of the Journal or reprints are free to educators.

Reprints of previously published articles (not all from the Journal) immediately available include:

"Professional Engineering Ethics in Practice," K. A. Meade, *Educational Relations Section, Public Relations Staff*

"How the Shell Mold Process is Applied in Industry," H. G. Sieggreen, *Central Foundry Division*

"Some Personal Lessons from Five Decades in Engineering," A. J. Altz, *Chevrolet Motor Division*

"How to Organize and Write Effective Technical Reports," R. A. Richardson, *General Motors Research Staff*, and C. A. Brown, *General Motors Institute*

"Empirical Methods Developed to Forecast Life of Self-enclosed Grease-lubricated Ball Bearings," H. D. Martin and P. J. Baker, *New Departure Division.*

Contributors to Jul.-Aug.-Sept. 1956 Issue of

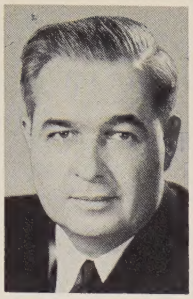
GENERAL MOTORS ENGINEERING JOURNAL

B. B. BROWNELL, co-contributor of "A Progress Report on the Development of the General Motors Aerotrain," is chief engineer of GM's Electro-Motive Division.

As chief engineer, Mr. Brownell is in charge of all engineering on Electro-Motive's commercial products. One aspect of this work entailed supervision of the design and engineering aspects of the new Aerotrain, about which he writes.

Mr. Brownell has over 20 years' experience in engineering with General Motors, having joined Delco Products Division as a test engineer in 1935. In 1937 he transferred to Electro-Motive as a junior electrical engineer. In 1939 he was promoted to assistant electrical engineer, and in 1943 he became assistant staff engineer. He was promoted to chief electrical engineer in 1946, taking over direction of engineering work involving design of traction motors, generators, and electrical control apparatus for Diesel locomotives. He became assistant chief engineer in 1953, assuming responsibility for design and development of the complete product line, and worked in this capacity until promoted to his present position as chief engineer in 1955.

Mr. Brownell was graduated from Massachusetts Institute of Technology, where he was granted the B.S. degree in electrical engineering in 1935.

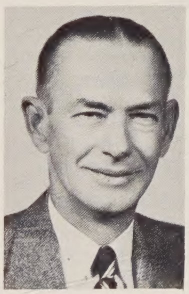


WILLIAM H. HARVEY, co-contributor of "A Progress Report on the Development of the General Motors Aerotrain," is coordinator of new products at Electro-Motive Division of General Motors, where he directs the developmental work on new products from their inception to the marketing stage. In this capacity he was closely concerned with the progress and development of the Aerotrain, of which he writes.

Mr. Harvey joined Electro-Motive in 1947 as director of industrial relations. In 1954 he was appointed coordinator of new products, having been active in this area of work the previous year.

He was graduated from Pennsylvania State College in 1937 with the B.S. degree. From 1937 to 1947 Mr. Harvey was assistant director of personnel relations, assistant to the vice president in charge of personnel and industrial relations, of Jones & Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

Mr. Harvey is a director of the Illinois Blue Cross Plan and is active in the Illinois State Chamber of Commerce, Employers Association of Chicago, and Industrial Relations Association of Chicago.



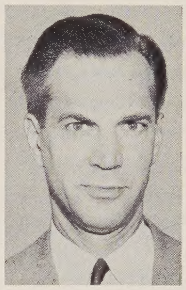
JOHN W. LOVETT, contributor of "Notes About Inventions and Inventors," has been a patent attorney in the Central Office of the General Motors Patent Section for over 25 years.

Mr. Lovett's duties are supervisory and cover miscellaneous special assignments. For many years he handled patent work of what is now Delco Appliance Division during their development of new products, including certain domestic appliances, oil and gas burners, furnaces, and boilers. Subsequently, he was engaged in the negotiation and drafting of patent license agreements and technical assistance agreements in connection with the manufacture by General Motors of military products for the government. Mr. Lovett was also engaged in work on patent phases of governmental contracts for development and supply.

Mr. Lovett attended The Ohio State University, pursuing courses in engineering. In 1921 he accepted an appointment to the United States Patent Office, where he served as a patent examiner in various grades until 1929, when he joined GM's Patent Section. While working with the government in Washington, D.C., Mr. Lovett completed his law studies and received the LL.B. degree from George Washington University in 1929.

Mr. Lovett is a member of the bar of the State of Michigan and has been admitted to practice before federal courts in the District of Columbia and several states, including Michigan.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.



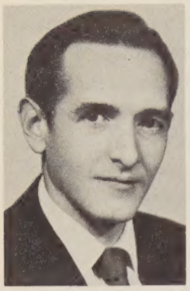
WESLEY W. McMULLEN, co-contributor of "New Test Facility Provides High-Capacity Air Flow for Automotive Air Cleaner Development," is a staff engineer in the Automotive Engineering Department of AC Spark Plug Division.

He joined AC as a student engineer in 1934 after having received the B.S.M.E. degree from the University of Michigan that same year. He served at AC in various capacities including junior engineer and senior engineer, and in 1947 he assumed his present position as staff engineer.

Mr. McMullen is in charge of air cleaners, silencers, and crankcase ventilation at AC. His previous projects were in these fields also and included work on both passenger cars and commercial vehicles, as well as military vehicles during World War II. During the War he was also assigned engineering duties on the Browning 50 caliber machine gun.

Mr. McMullen's work on crankcase ventilation has resulted in the grant of 2 patents.

He is a member of Tau Beta Pi, honorary society, and the S.A.E., subcommittee on carburetor air horn and throttle flange standardization.



GEORGE H. ROBINSON, contributor of "Bench Test Simplifies Search for Better Cam and Tappet Materials," is supervisor of ferrous metallurgy in the Metallurgical Engineering Department of the GM Research Staff. His duties cover supervision of experimental heat treatment of ferrous materials, investigation of service problems, and material developmental studies.

Mr. Robinson's work with the development of cam and tappet materials provided the information from which his article is drawn. His previous projects include investigation of service failures of automotive parts, such as transmission gears and rear axles; study of ball bearing durability; and developmental problems of various materials and heat treatment.

Mr. Robinson was originally employed by GM as a co-op student in the Metallurgical Engineering Department of the Research Staff in 1946. After his graduation from the University of Detroit in 1949 with the B.S. degree in chemical engineering, he became a graduate-in-training in the Physics-Instrumentation Department of the Research Staff for the summer. In 1950 Mr. Robinson received the B.S. degree in metallurgical engineering from Carnegie Institute of Technology and returned to the Metallurgical Engineering Department as a junior engineer. In 1954 he was promoted to senior research metallurgist and in February 1956 assumed his present position.

He is co-author of the paper "Interrelationship of Design, Lubrication, and Metallurgy in Cam and Tappet Performance," published by the S.A.E. in March 1955.

Mr. Robinson is a member of Tau Beta Pi, honorary society; the American Society for Metals, Papers and Program Committee of the Detroit Chapter; and the American Society for Testing Materials, Electron Metallography Subcommittee.

From 1943 to 1946 Mr. Robinson served as a Sergeant in the U. S. Army, receiving the Purple Heart at Okinawa in 1945.

GUY F. SCOTT, who prepared the problem "Determine the Output Torque of a Cam-Operated Indexing Mechanism for an Assembly Machine" and the solution appearing in this issue, is a senior project engineer in the Engineering Department of the Process Development Section, an activity of the General Motors Manufacturing Staff.

Mr. Scott's work on automatic assembly machine development serves as the basis for his problem and solution appearing in the JOURNAL.

From 1940 to 1944 he attended General Motors Institute, Flint, Michigan, working as a co-operative student at Chevrolet Motor Division's Commercial Body Plant at Indianapolis, Indiana. After receiving the graduate certificate from G.M.I. in 1944, he served as a Lieutenant with the United States Navy for 2 years. He returned to Chevrolet's Commercial Body Plant as a body layout draftsman in 1946. In January 1951 he joined GMC Truck and Coach Division as a plant layout engineer, transferring to the Process Development Section of the GM Manufacturing Staff in May 1951 as a project engineer. In 1954 he was granted the B.M.E. degree from G.M.I. and in June 1955 was promoted to senior project engineer in the Process Development Section.

Mr. Scott's technical affiliations include the American Society of Tool Engineers.

LEO L. YOUNG, contributor of "Fabrication of Welded Steel Crankcase for a Large 2-Cycle Diesel or Natural Gas Engine," has been general superintendent of manufacturing at Cleveland Diesel Engine Division since 1953. In this capacity he has charge of process engineering, tool design, standards, machine shop, and assembly. He had a large part in the planning and development of the tooling which was required for the crankcase described in his paper.

Mr. Young's work has centered around Diesel engine development and manufacture since he joined General Motors in 1936 as a design engineer with Cleveland Diesel. While working with the GM Research Staff, he was a member of the staff which designed the original Model 567 railcar Diesel engine. At Cleveland Diesel he worked as assistant master mechanic in 1947. He was promoted to master mechanic in 1948 and director of manufacturing facilities and services in 1951, in which capacity he served until being promoted to his present position as general superintendent of manufacturing.

As a member of the S.A.E., Mr. Young has served as advertising chairman, chairman of plant representatives, and chairman of Diesel activities. He attended Wayne University, Detroit, Michigan, and Fenn College, Cleveland, Ohio.

Before joining General Motors, Mr. Young was employed as a chassis designer and gained wide experience in the tool and machine tool fields.

GENERAL MOTORS ENGINEERING JOURNAL CHANGES TO QUARTERLY PUBLICATION

The GENERAL MOTORS ENGINEERING JOURNAL has been changed, effective with this issue, from a bi-monthly to a quarterly periodical. Library and indexing service recipients are asked to take special note that 1956 will bring five issues for Volume 3. This issue is Number 4 for the third quarter. Number 5 will appear in October for the fourth quarter. Comments on this change are invited from all recipients.

Additional quantities of the May-June issue of the GENERAL MOTORS ENGINEERING JOURNAL featuring the facilities and activities of the General Motors Technical Center are available to educators free on request. Articles of timely interest and full color reproductions cover the Research, Engineering, Manufacturing and Styling Staffs located at the Technical Center. Requests may be directed to the editor.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

Published by permission of Engineers' Council for Professional Development

GENERAL MOTORS ENGINEERING JOURNA